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F952-34

REVIEW OF THE FAA 1982 NATIONAL AIRSPACE SYSTEM PLAN

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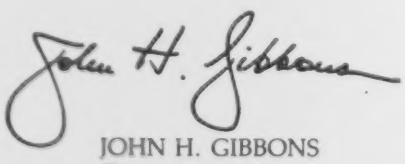
Foreword

In January 1982, shortly after OTA had concluded an assessment of the airport and air traffic control system, the Federal Aviation Administration released the 1982 National Airspace System (NAS) Plan. The Transportation Subcommittee of the House Committee on Appropriations asked that OTA undertake a review of the NAS Plan, building on the results of the assessment that had been carried out at their request.

OTA's approach to conducting this review was to examine the NAS Plan at two levels—the adequacy of the plan as a whole and the appropriateness of the specific technologies selected by FAA for implementation. Our aim was to make a balanced assessment—pointing out those parts that are commendable and supported by the aviation community while also identifying alternatives that merit consideration and indicating aspects of the plan that could be improved. In so doing, it was our intent to assist the congressional review process and to make a constructive contribution to the generally shared goal of modernizing and improving the air traffic control system in the years to come.

In conducting this review, OTA held extensive consultation with representatives of the aviation community and with technical experts in the fields of computer and communication technology. Workshops on aviation growth forecasts and air traffic control technology were held, and a 2-day conference of aviation experts was convened to evaluate FAA's planned modernization of the National Airspace System. The results of this consultative effort combined with analysis performed by OTA staff and the work carried out in the previous assessment form the basis for this OTA report.

In all, some 60 persons from outside OTA took part in the review of the NAS Plan. Their contributions were remarkable both for their depth and richness of insight and for the diversity of opinion on the strengths and weaknesses of the plan. We accept full responsibility for the analysis presented here, but acknowledge our debt to those who contributed so freely of their time and effort on our behalf. We are particularly grateful to the Congressional Budget Office for their assistance in analyzing traffic forecasts and funding issues.



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PART 1

The Review

EXECUTIVE SUMMARY

The National Airspace System Plan (NAS Plan) released by the Federal Aviation Administration (FAA) in January 1982 outlines the agency's most recent proposals for modernizing the facilities and equipment that make up the air traffic control (ATC) system. The plan attempts to integrate the various improvements into a single long-range program that addresses major shortcomings and reduces costs of the current system. Viewed on this high level—as a statement of policies, goals, and directions—the NAS Plan is to be commended as a significant and even bold step compared with past FAA efforts to chart the future evolution of the system.

The national airspace system is a "three-legged stool" made up of airports, the ATC system, and procedures for using the airspace. While all three need to be improved in an integrated fashion, the NAS Plan deals with only one leg—the ATC system. OTA's assessment of the airport and ATC system found that lack of airport capacity—not ATC technology—will be the principal limit on the growth of aviation. The NAS Plan acknowledges that "capacity limitations at busy airports will be the constraining element" in the system, but it concentrates on ATC technology, and most of the proposed improvements are directed at modernization of the en route, not the terminal area, portion of the system.

FAA does intend to address the problems of airports and airspace procedures. A revised plan for airport development is to be issued later this year. FAA has also just begun a National Airspace Review (NAR), a 42-month effort that will reexamine the rules and procedures governing the use of the airspace. Still, by issuing first a plan for modernizing ATC technology, without waiting until the other efforts have more thoroughly defined needs in the area of airports and airspace procedures, FAA may be placing too much emphasis on technological solutions. This perception is reinforced by the NAS Plan itself, which gives first priority to improved technology for the en route system by the late 1980's. There is little apparent advantage in seeking to move en route traffic more expeditiously only to have it encounter delays in terminal areas, where capacity improvements are not scheduled to be made until the early 1990's.

With these reservations, the FAA plan for ATC system improvements is comprehensive. The proposed changes are technologically feasible, and they are consistent with the goals of increasing safety and productivity and accommodating future growth. Providing capacity to accommodate anticipated growth was a principal factor in developing the NAS Plan, although other factors were also involved—increased reliability, safety, productivity, and fuel savings. Still, the technological strategy and implementation schedule appear to have been driven by forecasts of aviation growth and near-term capacity problems at en route centers. FAA traffic and workload forecasts have tended to be too high in the past, however, and in some cases technological alternatives that might be equally effective or less costly than those selected by FAA appear to have been rejected because of the anticipated rate of growth in demand for ATC services. OTA's review of the NAS Plan suggests that FAA forecasts may not be a useful guide to long-term planning and investment, and that some of these technological options may therefore warrant reexamination.

In the area of en route computer replacement, for example, some believe it would be prudent to adopt a strategy for interim steps to be taken in the 1980's that imposes no constraints on the design of the new system that will serve for the 1990's and beyond. FAA's proposed approach is to "rehost" the existing software on new computers, and then to develop new software to run on the host computers for use with the advanced sector suites to be installed by 1990. Several experts have told OTA that this approach might limit the options available in designing the new system. In their view, any interim host would have to be replaced when the new system comes on line. FAA admits this possibility, but maintains that the intent is for the host computer to serve as the basic processor for the ATC system until well into the 1990's. An alternative short-term approach would be to make selective enhancements to the present technology—i.e., upgrade the current computers in the centers where capacity problems are

expected—in combination with economic or regulatory approaches to demand management, while proceeding *without delay* on a parallel effort to develop by 1990 a totally new ATC system design that makes best use of technologies then available and that will serve until beyond the turn of the century.

As a blueprint for the modernization of the ATC system, the 1982 NAS Plan does not provide a clear sense of the priorities or dependencies among its various program elements. Nor does the plan deal explicitly with contingencies or delays caused by engineering problems or by the possible deletion of some elements due to budgetary constraints. Given the complexity and magnitude of this undertaking, FAA may have set itself an overly ambitious schedule for implementing the proposed improvements.

OTA's review of the 1982 NAS Plan has also identified the following specific findings and issues:

- *Growth.*—FAA's traffic forecasts have been too high in the past and there are questions about the methodologies and assumptions underlying the projections on which the NAS Plan is based. Overestimation may have led FAA to foreclose technological options and accelerate the implementation schedule unnecessarily. It may also have led FAA to overestimate the user-fee revenues that will be available to pay for the proposed improvements.
- *En Route Computer Replacement.*—FAA's option analysis issued in January 1982 supports upgrading the 10 en route computers that face capacity problems.[1] The NAS Plan, released at about the same time, calls instead for replacing the computer hardware (called rehosting the software) in all 20 centers as a part of a long-term plan to increase productivity and reliability as well as capacity. OTA does not find persuasive the reasons advanced by FAA for rejecting the previously preferred option of upgrading only selected en route centers. In addition, the choice of a host computer now may limit the options available to the contractor for the sector suite and software. OTA conferees were sharply divided in their views on this question. Some felt that the choice of a host computer now might limit future ability to benefit from a distributed computer architecture, local area networking, and new techniques in software development. Others believed that, if the host is chosen judiciously, the transition to a new system embodying these advanced and desirable features could be made without difficulty.
- *Automation.*—While the NAS Plan envisions substantial cost savings due to extensive automation, supporting analysis is not provided in the plan. This analysis is probably still in progress and may take some time to complete, but it would be useful for the interim results to be made available to assist in congressional review of the automation portions of the overall plan. In addition, there is concern on the part of some experts about the ability of human operators to participate effectively in such a highly automated system and to intervene in the event of system error or failure.
- *Satellites.*—Satellite technology has significant potential applications for communication, and eventually for surveillance and navigation. FAA does not see a role for satellites in the period covered by the NAS Plan. FAA's decision against satellites appears to have been driven by timing and present cost effectiveness, rather than technology readiness or long-term system advantages.
- *User Effects.*—A great many of the proposed ATC system improvements are directed to the needs of traffic operating under the instrument flight rules (IFR), particularly while en route at cruise altitude. These improvements will benefit FAA itself by automating functions and reducing labor costs. The principal beneficiaries among users will be air carriers and larger business aircraft. Personal general aviation (GA) users could receive improved weather information, an important benefit; but in order to obtain this benefit and other operational advantages of the new sys-

[1]Federal Aviation Administration, "Response to Congressional Recommendations Regarding the FAA's En Route Air Traffic Control Computer System," report to the Senate and House Appropriations Committees pursuant to Senate report 96-932, DOT/FAA/AAP-82-3, January 1982.

tem, more avionics will be required, and there would be restrictions on access to airspace by aircraft not so equipped. The Department of Defense (DOD) too, is concerned about the cost of new ATC avionics and feels that the new plan must be carefully coordinated with the military services to ensure that their mission needs and responsibilities for administration of the airspace are integrated with those of FAA.

- *Cost and Funding.*—Implementing the improvements proposed in the 1982 NAS Plan would more than double FAA's facilities and equipment budget through 1987, compared to the last 10 years. FAA has not yet released cost estimates for completing the proposed programs, but it seems likely that expenditures of like magnitude will be needed in the years beyond 1987. FAA proposes to recover 85 percent of its total budget through user fee revenues and a drawdown of the uncommitted Trust Fund balance. The user fee schedule would perpetuate the existing cross-subsidy from airline passengers and shippers of air cargo to GA. Business aviation would benefit particularly because of the extensive use these aircraft make of the IFR system. In addition, higher user fees may dampen the growth of aviation, thereby reducing the revenues expected to pay for the proposed improvements.

THE AIRPORT AND ATC SYSTEM

BACKGROUND

In December 1981, OTA completed an assessment of the airport and ATC system, with emphasis on the problem of congestion at major hubs and the feasibility, cost, and impacts of prospective improvements in ATC technology. This assessment drew on information published by FAA through 1981 and focused on three central topics:

- scenarios of future aviation growth;
- alternatives for increasing airport and terminal area capacity; and
- ATC system modifications proposed by FAA.

In January 1982, FAA issued a new NAS Plan for the modernization of the ATC system through the year 2000. The House Committee on Appropriations, Subcommittee on Transportation, which had requested the original OTA assessment, asked OTA to undertake a 3-month follow-on study to review the 1982 NAS Plan and to provide the subcommittee with the following support:

- a critique of the NAS Plan, with emphasis on changes from previous proposals;
- a delineation of technological options and alternative implementation strategies within the general framework of the Plan; and
- an analysis of issues raised by the Plan, such as benefits and costs to airspace users and the Government, and identification of questions needing further study or clarification.

The NAS Plan proposes many improvements to the ATC system—including replacement of computers, increased automation, modernization of the communication network, consolidation of ATC facilities, and upgrading navigational aids. OTA's review focuses on the computer replacement, communications, and automation issues that are the heart of the Plan.

OTA's response to the subcommittee's request draws on the findings of the recently completed assessment, which are outlined below, supplemented by a series of meetings with representatives of the aviation community and experts in the fields of computer and communications technology. Working Group No. 1 met on February 25, 1982, to discuss aviation growth scenarios and to examine the specific methodology and economic assumptions underlying the aviation forecasts on which FAA based the 1982 NAS Plan. Working Group No. 2 met on March 9, 1982, to discuss the specific computer and communications technologies proposed by FAA, alternative technologies that are not included in the NAS Plan, and the technical and scheduling risks involved in FAA's proposed implementation strategy. OTA also held a general conference of aviation and ATC technology experts on April 1 and 2, 1982, to discuss four major issues arising from the NAS Plan: aviation growth, proposed changes in ATC technology, effects on airspace users, and strategies for funding system improvements.

BASIC FINDINGS ON THE AIRPORT AND ATC SYSTEM

OTA's assessment of the airport and ATC system arrived at several major findings, which have been generally confirmed by the subsequent review of the 1982 NAS Plan. Findings related to technological options are discussed later in the section entitled "Specific Technologies." OTA findings in other areas are summarized below.

- *Congestion and delay in the system result primarily from the concentration of air traffic at a few major hub airports.*—There are over 6,000 public-use airports in the United States, of which 435 have FAA control towers. However, the 10 busiest airports handle 33 percent of all commercial operations and 47 percent of all passenger enplanements. The Nation's 60 major metropolitan areas account for 90 percent of all enplanements, 75 percent of all commercial operations, and 40 percent of all itinerant aircraft operations, including GA.

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- *There will be continued growth in the demand for ATC services through 2000, but the rate of traffic growth will be lower than in the last 20 years and probably lower than projected in FAA aviation forecasts.*—FAA forecasts have consistently overestimated traffic growth in the past, and the latest forecasts still seem too high. A number of factors suggest that the air carrier industry is already approaching its mature size and will grow slowly over the next two decades. FAA workloads will continue to increase, however, due to the continued growth of the GA sector. Between 1970 and 1980, GA traffic accounted for 72 percent of the increase in IFR tower operations and 62 percent of the increase in en route operations. GA aircraft, particularly turboprop and jet business aircraft, can be expected to generate about 65 percent of the increase in these FAA workloads between 1980 and 1990. By 1990, business aircraft will account for about half of all demand for ATC services.
- *The future growth of air traffic will aggravate congestion problems and spread them to additional airports.*—Unconstrained growth of operations at major hubs would lead to serious congestion at anywhere from 20 to 50 airports by 2000, depending on economic growth rates, compared to 5 or 10 airports before the 1981 strike. Unless there are capacity increases to relieve congestion at major hubs, there will be a redistribution of air carrier operations to "second-tier" hubs and increased diversion of GA traffic to reliever airports. Such a redistribution is already in progress as a result of market forces and FAA traffic restrictions at 22 congested hubs.
- *The principal constraint on the future growth of aviation will be the lack of airport capacity.*—Major improvements to increase capacity in congested hubs—new runways or new airports—are unlikely in the near future due to high cost, lack of land, and community resistance to airport noise. The principal opportunities for capacity expansion will come at second-tier airports and at GA and reliever airports that can accommodate traffic diverted from congested air carrier airports. However, the construction of independent, IFR-equipped "stub" runways to separate slower GA and commuter aircraft from larger jet aircraft could significantly increase the volume of traffic that can be handled at some large air carrier airports.
- *There are three basic forms of response to airport and airspace capacity problems: technological, economic, and regulatory.*—Changes in ATC technology and procedures can produce small increases in capacity by allowing airspace and runways to be utilized more efficiently. However, the major increases to be derived from technology will not be realized until advanced systems such as automated metering and spacing; microwave landing system; and wake vortex detection, prediction, or reduction are developed and deployed by the end of this decade or later. In the interim, congested airports will have to make use of demand-management alternatives—including economic measures such as peak-hour pricing and regulatory measures such as slot-allocation quotas or access restrictions—in order to shift traffic to a place or time when it can be handled more effectively.
- *All three approaches will be used, and the combination or emphasis will reflect both local conditions and a more fundamental policy decision: can the Nation continue its past practice of accommodating aviation growth wherever and whenever it occurs, regardless of the cost; or is growth to be managed and directed so as to make economical use of existing resources and capacity.*

THE 1982 NATIONAL AIRSPACE SYSTEM PLAN

GENERAL COMMENTS

The stated objectives of the 1982 NAS Plan are to achieve a significantly safer and more efficient national airspace system over the next 20 years, while constraining costs incurred by the Government and airspace users. The Plan attempts to integrate the various improvements to the ATC system into a single long-range program, while eliminating major deficiencies and costs of the current system.

Viewed on this high level—as a statement of policies, goals, and directions—the Plan is to be commended as a significant and even bold step compared to previous FAA efforts to chart a future course for the ATC system. It provides a statement of objectives and the rationale for the proposed program of system improvements. The Plan identifies capital investments needed to modernize and consolidate ATC facilities in order to meet future demand and to reduce operating and maintenance costs. The document reflects a conscious effort to provide improved services to airspace users, to promote system efficiency, and to minimize costs both to those who fly and to the FAA. This is a marked improvement over previous NAS Plans, which have tended to be little more than catalogs of proposed new equipment and engineering changes. But is is not without faults.

ADDRESSING FUTURE REQUIREMENTS

The needs of civil aviation represent what one participant in the OTA's Conference called a "three-legged stool," made up of airports and terminal area airspace, rules and procedures, and ATC technology. All three areas need to be addressed in a timely and coordinated manner.

The NAS Plan itself acknowledges that "capacity limitations at busy airports will be the constraining element" in the system, yet it fails to address solutions to airport capacity problems and devotes only 12 of its 450 pages to the place of airports in the NAS. A new version of FAA's National Airport System Plan is expected to be released in the fall of 1982, and there is concern that, as in the past, it will be an uncoordinated catalog of State and regional plans. FAA has programs under way to identify and evaluate techniques for increasing airport capacity, and it would be desirable for FAA to integrate its plans for future airport development with those for ATC facilities and equipment.

In cooperation with airspace users, FAA has also begun a National Airspace Review (NAR) to study possible changes in ATC procedures and flight regulations. Changes in ATC procedures (like changes in airport plans) could have a profound effect on ATC requirements, and coordination between NAR and the plan for equipment modernization is vital. NAR has just begun and will take 42 months to complete, and by then FAA may have made a commitment to many of the equipment changes outlined in the NAS Plan.

There is a recognized need for improvements in the ATC system and, given the long leadtimes involved, these improvements should be set in motion as soon as possible. As a practical matter, FAA needs a long-term modernization plan—complete with a long-term approach to funding—to ensure that the plan can be carried out. However, this requires a realistic sense of both the requirements that will be placed on the system by future growth and the opportunities that will be available in computer and telecommunication technology, as well as sufficient flexibility to exploit those opportunities in order to meet those requirements.

Because it attempts to fit all the new technological elements into a coherent system framework, the FAA considers the current NAS Plan a "blueprint" for future system evolution, indicating the steps that will be required and when they will be carried out. The Plan, however, is not a full and specific description of system development, acquisition, and deployment—nor is it really intended to be. Important details of engineering and testing for each subsystem remain to be set forth in technical documents scheduled for issue in the coming months. The Plan should thus be viewed as only the apex of a pyramid of plans and specifications for new equipment and facilities.

Within these limitations, the ATC system improvements proposed by FAA are technologically feasible and desirable with respect to safety, capacity, and productivity. Nevertheless, there are alternatives that might be equally effective and, given the uncertainties in FAA's traffic and demand forecasts, it would be prudent to adopt an implementation schedule that neither forecloses potential options nor constrains the final system design. FAA's proposed en route computer replacement program in particular has been criticized on this score. The Plan requires the coordination of many disparate projects, many involving considerable technical or schedule risks, yet it lacks a clear statement of priorities and provides no alternatives or contingencies in the event of problems, delays, or budget constraints.

PRIORITIES

While the 1982 NAS Plan states the goals that will guide the development process, it does not relate these goals to specific programs in a systematic fashion. Presumably there is a hierarchy among goals and among programs that will contribute to achieving these goals, but nowhere in the Plan are these priorities delineated. If, because of budgetary constraints or failure to meet engineering objectives, there are items that must be eliminated or schedules that must be altered, the Plan does not make clear what effects this would have on the development of the system as a whole. Nor is it made explicit how elements of the Plan could be eliminated or rescheduled in such a way that major objectives are not compromised.

A valuable feature of the Plan is material in the introductory chapter stating the rationale of the planning process and describing the steps that FAA went through to identify requirements, analyze options, and lay out a course of action. It might be hoped that FAA will carry this explanation one step further by describing the logical dependencies among elements of the Plan—i.e., an explanation of how each element supports others and how they contribute to particular objectives. The Plan is replete with development flow diagrams for each level of the system, but these charts show little more than the temporal sequence of events, the merging of development streams over time. The diagrams, and the accompanying text, do not indicate critical paths and the specific relationships to safety, capacity, and productivity.

SCHEDULE

A major shortcoming of the Plan as a planning document is that the development and deployment schedule is not tied directly to specific components of aviation growth or to the needs for particular services at certain times and places. FAA's approach seems to be to implement the entire plan as expeditiously as possible to prevent the ATC system from being overwhelmed by growing demand. However, as FAA's own forecasts indicate, growth is expected to occur at dif-

ferent rates in different regions and among user groups. This pattern of growth may impose requirements not addressed by the NAS Plan.

For example, the Plan states that the major factor constraining the future growth of aviation will be the lack of capacity at major airports. Yet, the first part of the ATC system scheduled for modernization and increased capacity to handle traffic is the en route system. Terminal area improvements, some of which could ease airport capacity constraints, are not planned for installation until the 1990's. Giving priority to improvements that would increase the throughput of en route centers does not seem entirely consistent with the forecasts of where the capacity of the system will be most severely limited. There is little apparent advantage in moving en route traffic more expeditiously only to have it encounter delays in terminal areas where capacity improvements are not scheduled to be made until the early 1990's.

FAA has also set itself a complex task of system development and deployment—more complex than any it has attempted before—and there is room for doubt about the prospects of keeping to the time line laid down in the Plan, especially since there are so many elements and paths of development that must be coordinated.

En route automation, for example, involves two major procurements—the rehost computer, and then new software and sector suites. FAA's proposed strategy is a complicated process that involves selecting from all competitors two "finalists" for each of the two major procurements. These finalists will then be asked to demonstrate their proposed system at the Test Center in Atlantic City, after which a production contract will be awarded to one of each pair.

For just one of the many NAS Plan programs, therefore, FAA is placing itself in a position where it must manage four major contractor efforts at the same time. The work of these contractors, and possibly several subcontractors, must be coordinated and kept on schedule. Equally important, the contractors must be kept insulated from each other to preserve competition and protect proprietary information. A less complicated strategy might have better chances of success, given the management problems inherent in this approach. If FAA concludes that its proposed approach of directing four contracts at one time is to be preferred, then—as a minimum—the agency should take additional steps to increase its internal capability in the area of systems acquisition management and should plan to strengthen the role of an outside system integration contractor. FAA recognizes this need and has recently announced internal management changes to improve these capabilities.

In the face of the uncertainties about future growth, and in view of the difficulties of keeping the parts of a complex development program on schedule, it is surprising that the 1982 NAS Plan does not deal explicitly with contingencies or the effects of schedule slippage. No endeavor of this scope and complexity can reasonably be expected to adhere to a nominal schedule. There are inevitable engineering problems; delays will occur even with the best of management; unforeseen circumstances will arise. One participant in the OTA working group on computer and communication technologies characterized the schedule as a "no-problems scenario," admirable for its conception but not realistic in view of the manifold implementation problems that might be encountered.*

*As this report was being prepared for publication, the General Accounting Office released its review of the NAS Plan (Examination of the Federal Aviation Administration's Plan for the National Airspace System—Interim Report, AFMD-82-66, Apr. 20, 1982). GAO's findings very closely parallel OTA's on several major points. They found that the NAS Plan lacks the detail and justification usually needed for budgetary approval and implementation. They also found that FAA's proposed en route computer replacement strategy poses both short-term and long-term risks, and they advise that FAA consider less risky alternatives—among them conversion of 9020As to 9020Ds. GAO points out that FAA has not yet developed a careful and detailed transition plan, which is essential to an effort of this magnitude and complexity. Finally, GAO raises questions about FAA management and adminstrative resources and advises FAA to strengthen its capability in this area as a matter of first priority.

FAA AVIATION FORECASTS

Accommodating the anticipated growth of air traffic and ATC workloads has been a primary justification for proposed system improvements. In the past, however, FAA's long-term forecasts have generally proven to be too high. This raises questions about the usefulness of FAA's traffic and workload forecasts for 10 years and beyond as a guide to long-range planning and investment decisions. For example, FAA forecasts the onset of delay problems by the late 1980's. This forecast underlies the proposed approach to en route computer replacement, a decision that sets the pace and direction for overall system modernization. That decision, if taken, may unjustifiably limit the options available for the final system design.

OTA's review indicates that the growth projected by FAA may well ultimately occur, but there is *sufficient uncertainty about near-term* growth that any program for upgrading the system should emphasize a design that can be adapted to less growth (or more growth) without a fundamental change in the system. Questions about the accuracy and usefulness of FAA aviation forecasts stem from three principal concerns:

- historical accuracy of FAA forecasts;
- forecasting methodology used by FAA, including the ability of FAA forecasts to account for noneconomic influences on aviation growth;
- specific assumptions underlying the forecasts on which the 1982 NAS Plan is based.

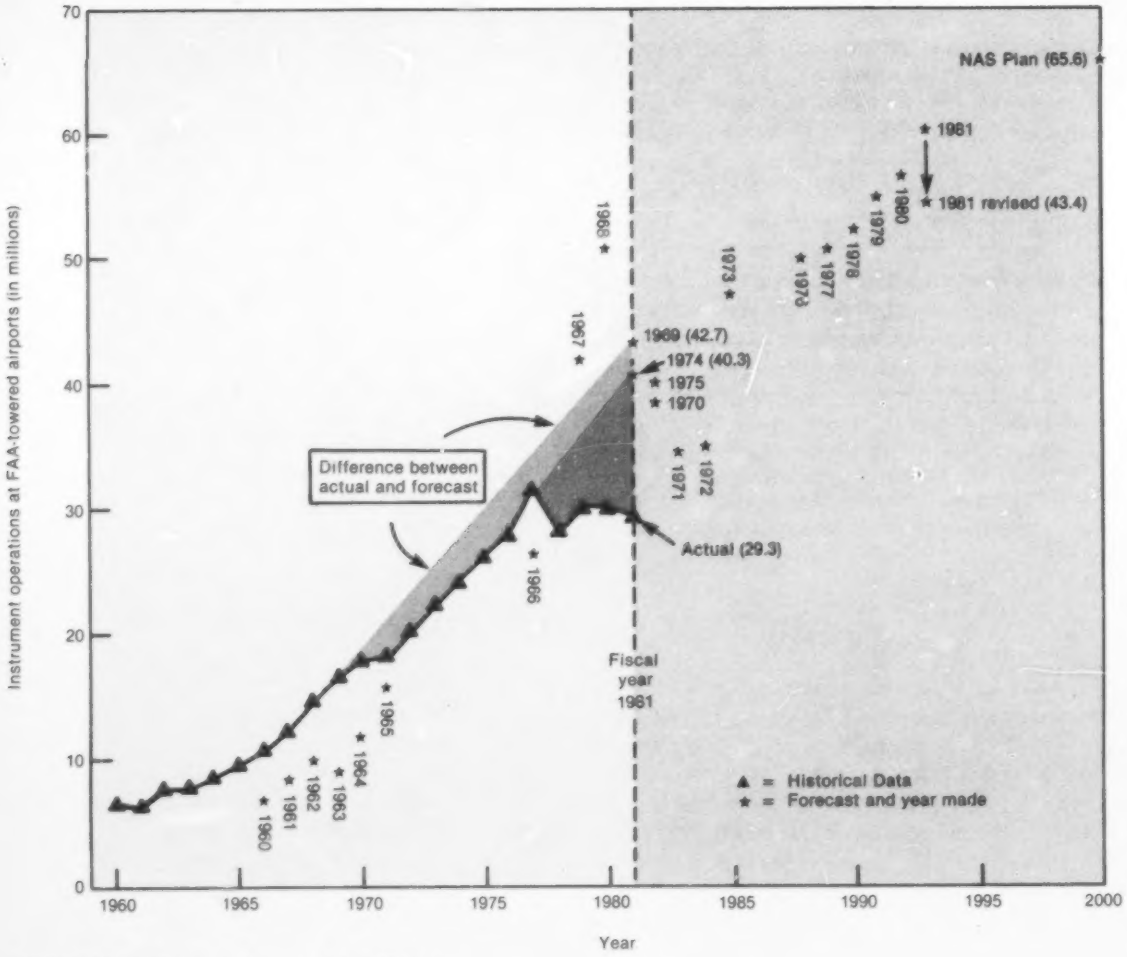
ACCURACY OF PAST FORECASTS

Recent FAA forecasts of air traffic and ATC workloads have tended to be much higher than actual results. After underestimating growth in the early 1960's, the long-range (10-year) projections for the past 15 years have consistently been too high, often by 50 percent or more. Figures 1, 2,and 3 compare past forecasts with actual workloads at FAA towers, en route centers, and flight service stations. They show that the workloads originally projected for fiscal year 1981 (in 1970) were between 50 and 180 percent higher than what actually occurred. Alternatively, one could conclude that the forecasts were off by a decade since the levels of demand once predicted for 1981 are now expected in the 1990's or later. FAA nevertheless believes the current forecasts to be sufficiently accurate that they can serve as the basis for planning long-term system improvements.

Analysis by the Congressional Budget Office (CBO) of the accuracy of FAA forecasts shows a similar pattern (table 1). Five-year forecasts of tower operations made during 1959-65 for the years 1964-69 averaged 19 percent too low, while the 1966-73 projections for the years 1971-78 averaged almost 33 percent too high. Starting in 1974, FAA initiated a new and much improved econometric methodology for forecasting passenger enplanements and revenue passenger miles (RPMs), and the accuracy of these projections has subsequently improved.

However, ATC workloads are driven not by enplanements or RPMs but rather by operations —takeoffs and landings—and the 1974-76 projections of total tower operations for 1979-81 remained too high by an average of over 21 percent. Forecasts of total *instrument* operations at FAA towered airports—a more useful indicator of ATC workloads—have been somewhat more accurate, as have forecasts of IFR aircraft handled by en route centers. Flight Service Station workload projections have been the least accurate of the relevant forecasts.

Figure 1.—FAA Tower Workload, Actual and Forecast, 1960-2000



SOURCE: Office of Technology Assessment, from FAA data.

Figure 2.—FAA En Route Workload, Actual and Forecast, 1960-2000

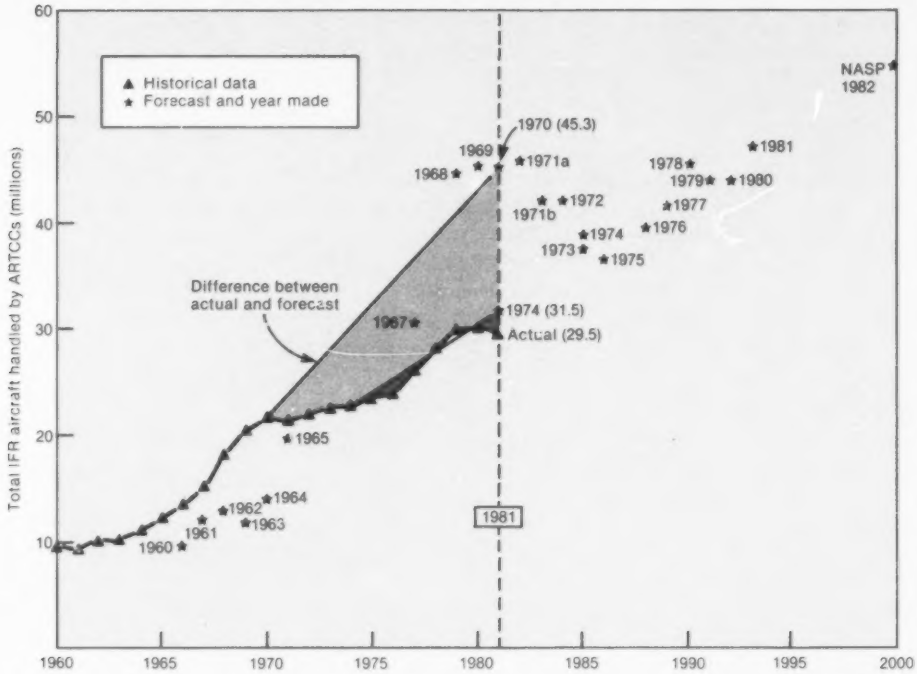


Figure 3.—FAA Flight Service Workload, Actual and Forecast, 1960-2000

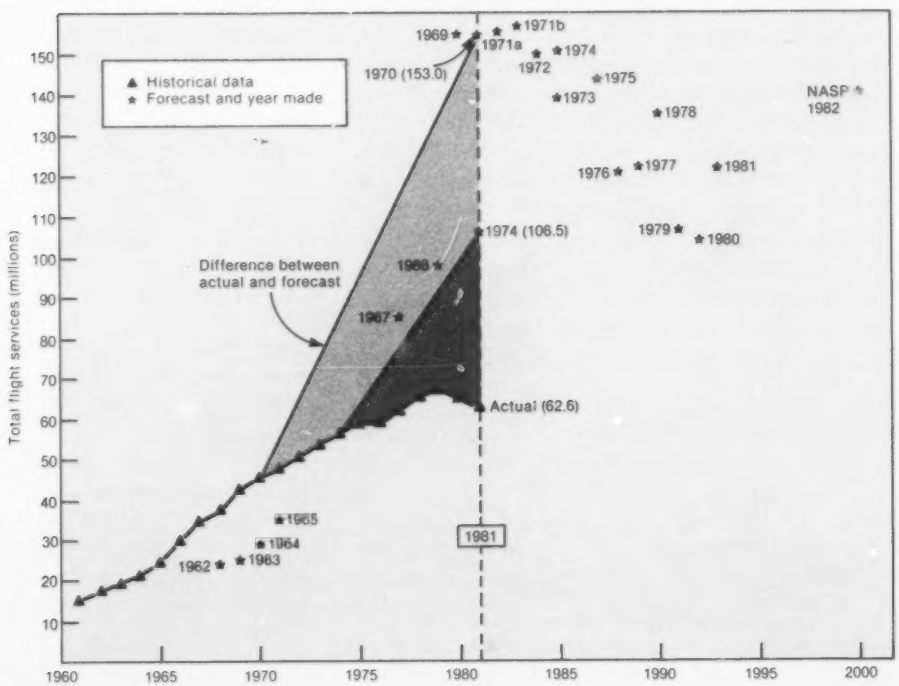


Table 1.—FAA Forecasts Compared With Actual Data (percentage difference)

Forecast year	For the year	Total commercial air carrier enplanements	Total revenue passenger miles	Hours flown in general aviation	GA operations at FAA towers	Itinerant operations at FAA towers	Total operations at FAA towers	Instrument operations at FAA towers	IFR aircraft handled at FAA ARTCCs
1959	1964	− 1.3	− 6.5	− 0.6	4.6	6.0	9.7	− 4.8	11.7
1960	1965	− 9.5	− 9.7	− 1.2	−27.8	−12.7	−21.6	0.3	−12.8
1961	1966	−27.5	−26.0	−15.3	−37.7	−20.0	−28.9	−28.0	−14.8
1962	1967	−32.1	−31.4	−23.6	−34.7	−20.6	−27.3	−25.6	−19.2
1963	1968	−41.3	−41.3	N/A	−38.4	−26.9	−32.5	−41.8	−24.5
1964	1969	−31.4	−33.6	−23.5	−27.3	−24.0	−24.9	−31.7	−23.8
1965	1970	−14.1	−19.8	−16.3	− 2.6	− 8.0	− 5.2	−16.0	−11.7
1966	1971	9.4	0.5	− 1.6	53.7	32.4	42.2	0.6	− 1.4
1967	1972	23.6	13.0	9.1	72.5	43.8	54.9	22.7	25.5
1968	1973	23.9	15.9	7.4	78.3	49.7	58.4	18.2	19.7
1969	1974	21.1	21.2	4.6	53.6	37.7	42.4	− 2.1	22.7
1970	1975	26.3	33.0	− 0.6	60.9	19.7	25.9	−15.6	15.3
1971	1976	19.0	28.6	− 0.6	42.9	14.1	22.9	−16.4	9.2
1972	1977	22.3	33.7	− 6.8	36.9	1.2	4.5	− 2.0	11.2
1973	1978	14.0	18.3	−10.4	14.8	2.3	8.8	− 3.6	− 0.7
1974	1979	− 9.7	− 7.4	−13.7	11.8	2.2	9.4	− 2.2	− 2.7
1975	1980	−10.6	−17.3	− 0.2	34.6	15.6	25.7	− 7.1	− 3.7
1976	1981	4.3	− 1.8	15.7	41.3	24.3	32.1	4.6	4.8

SOURCE: Congressional Budget Office, from FAA Aviation Forecasts, 1959 to 1976.

FORECAST METHODOLOGY

CBO's analysis of FAA forecasting models identified several methodological features that may account for at least part of the inaccuracy of FAA's forecasts. As noted earlier, the econometric models used to project enplanements and RPMs have proven to be far more accurate in recent forecasts. However, the methods for translating enplanements and RPMs into projected operations —based on assumptions about average load factor, aircraft size, and stage length—appear to be far less sophisticated. FAA's 5-year forecasts of air carrier enplanements have been off by only about 1 percent since 1974, while projected operations have been more than 20 percent too high. This discrepancy is explained in part by airlines using larger aircraft, with higher load factors, on longer routes.*

Another likely cause of error in forecasts of operations is the methodology FAA uses for projecting GA fleet size, operations, and resulting ATC workloads. In the FAA model, changes in the projected size of the GA fleet are driven primarily by changes in the gross national product (GNP) and to a lesser degree by aircraft prices and interest rates. Changes in fuel prices, however, are implicitly assumed to have no measurable effect on the growth of the GA fleet. This omission has a strong influence on the resulting forecasts of workloads imposed on the ATC system by the GA sector, because fleet size is the only causal variable used in projecting GA instrument operations at FAA towers. Likewise, forecasts of local and itinerant GA operations, as well as GA demand for flight services, are driven primarily by fleet size and only to a much smaller extent by fuel price or other variables. A number of other judgments clearly enter into these calculations, but they are not explicitly made, and their influence on the results is unclear.

These questions about GA forecasting methodology have an important bearing on overall system planning and investment, because so much of the anticipated growth in ATC demand is expected to come from the GA sector. FAA forecasts that the GA fleet will grow by 50 percent between 1980 and 1990, and that during the 1980's GA aircraft will account for 65 percent of the increased workloads at FAA towers and en route centers, and 75 percent of the increase in flight services. Yet the size of the GA fleet is assumed to be driven almost entirely by growth in GNP and personal

*This difficulty is not unique to FAA. Boeing and others cite problems in anticipating airline route structure and load factors as a source of error in their forecasts.

income, with little or no allowance for saturation in this market—a potential problem in forecasts covering 10 or 20 years. This also raises questions about the economic projections and other assumptions underlying the aviation forecasts on which the 20-year investment program of the NAS Plan is based.

GROWTH ASSUMPTIONS IN THE 1982 NAS PLAN

Economic assumptions, particularly about highly aggregate variables such as GNP and disposable personal income, are the principal drivers in FAA's forecasts, and the projections are very sensitive to changes in long-term growth rates. Past FAA forecasts included three or four alternative scenarios to allow for the uncertainties of future economic growth, with the "baseline" scenario being the most likely foreseeable outcome. These scenarios were previously based on economic indicators prepared by Wharton Econometric Forecasting Associates using their Long-Term Industry and Economic Forecasting Model. Between 1976 and 1981, the range of these scenarios became both wider and lower, indicating greater uncertainty about future trends and less optimism about the probability of continued rapid growth.

In the September 1981 forecasts, however, the baseline scenario was based on economic projections supplied by the Office of Management and Budget (OMB). These OMB projections were later withdrawn and, due to uncertainties caused by the Professional Air Traffic Controllers Organization (PATCO) strike, the resulting FAA forecasts were also discarded before publication—"sent to the shredders instead of the printers," in the words of FAA's Director of Aviation Policy and Plans. Revised 1981 aviation forecasts based on new OMB economic projections were not released until February 1982; the NAS Plan itself is based on FAA's 1980 forecasts and Wharton's March 1980 economic projections, which do not reflect recent changes in aviation and the general economy. These economic forecasts and aviation growth projections were the subject of considerable criticism by aviation experts during OTA's review of the 1982 NAS Plan. Several members of Working Group No. 1 observed that the administration's numbers should be considered "targets" rather than projections. Compared to Wharton's, they tend to show higher growth rates for GNP, and lower growth rates for inflation and fuel prices, resulting in a higher long-term growth rate for air trffic. Some participants questioned whether aviation could in fact continue to grow as fast as it had in the 1970's, given the current financial plight of the airlines and the recent softening of the GA market. While disagreeing with FAA's short-term projections, however, they recognized the danger of allowing long-term forecasts to be overly influenced by current economic conditions.

CONSTRAINTS ON FUTURE GROWTH

FAA's mission to foster civil aviation creates a planning process that naturally avoids the risk of imposing fundamental constraints on the growth of air traffic. It may even be better for FAA to err on the high side rather than the low side, although such predictions may become self-fulfilling prophecies to the extent that providing additional services begets additional demand. As a result, FAA's forecasts are unconstrained—they assume that past trends will continue, that there will be no limits imposed on growth, and that the proposed improvements will be made when and where needed to accommodate growth. But there are a number of factors other than the ATC system itself that could change these trends or restrict future growth. These events and influences, most of which are neither accounted for in FAA forecasts nor addressed in the 1982 NAS Plan, include the following:

- *Airports.*—The NAS Plan recognizes that congestion at major hubs and relievers is a

cause of special concern, but the availability of GA airports will also be a widespread and serious constraint on growth. Although there has been a net increase in the overall number of airports in the last 15 years, over 300 GA airports have been closed or abandoned *each year* since 1965 and there has been a steady shift toward privately owned, private-use airports. The result, particularly in metropolitan areas, is a decrease in the number of public-use landing places and growing inconvenience in owning an aircraft. Both factors will influence the growth of general aviation. "One way to test the realism of doubling the fleet," according to one aviation consultant, "is to try to figure out where they're going to put them with the present trend in runways, ramps, and tiedowns."

- *Fuel Price.*—The greatest uncertainty facing domestic aviation in both the short and long term is the future price and availability of aviation fuels. This uncertainty can cause sudden shifts in FAA forecasts: those in the 1982 NAS Plan (based on September 1980 data) assume an average real increase in fuel prices of 3 percent per year through 1993, while the revised 1981 FAA forecasts (released in February 1982) assume real *decreases* during 1982-83 and an average real increase of only 1 percent per year during 1984-93. No long-term shortage is anticipated in either forecast. The current "oil glut" and price decreases may be transient events, however. In addition, there are indications that aviation gasoline (used by smaller piston-engine GA aircraft) may become increasingly difficult to obtain; more likely to reduce personal GA than the business, corporate or air-taxi operations that place more demand on the ATC system.
- *User Fees.*—The 1982 NAS Plan indicates that the cost of upgrading the ATC system will be borne by the users, but the 1980 traffic forecasts on which the NAS Plan is based do not reflect the administration's user fee proposals. Sudden large increases in fuel taxes could depress traffic, a situation the proposed "escalator" schedule is designed to avoid. Nevertheless, cost recovery through user fees could affect both the demand and the funding for planned system improvements.

  Many experts feel that previous user fees had a small restraining effect on GA growth in the 1970's and that the original administration proposal of a 65¢/gallon tax on GA jet fuel would have had a dramatic effect on use of the system by business aircraft. The current user fee proposals will have less effect on precisely that part of GA traffic which is placing increasing demand on the system. As with fuel prices, however, the FAA model is not sufficiently sensitive to give an accurate estimate of this effect.

  Furthermore, if future traffic levels turn out to be significantly lower than projected by FAA, total revenues from airspace users may also fall short of the levels required to carry out the proposed improvements. Current FAA and OMB forecasts show steady increases in both traffic and user fee revenues, with user fees paying for 85 percent of total FAA costs by 1987 (see "Cost and Funding Issues").
- *Aircraft Technology and Financing.*—Recent improvements in airline productivity have come from higher utilization and economies of scale rather than aircraft technology, and further improvements are likely to come more slowly than in the last 20 years. The development of a new generation of advanced-technology aircraft will depend on the potential market, which in turn depends on airline profitability. Some near-term increases in fleet efficiency could be achieved by retrofitting existing aircraft. Airline profits are at all-time lows, however, and capital requirements for new equipment would demand record levels of return on investment through 1990.
- *Deregulation and Industry Structure.*—Airline deregulation has destabilized the industry's price and market structure, causing over competition and low profitability that increase the risks and uncertainties of airline financing. Some analysts feel that the demise of some carriers may be a natural and desirable result of complete deregulation, and a

few predict the failure of a major carrier by mid-1982.* Restructuring of the industry through bankruptcies or mergers might remove overcapacity, and the survivors might be in a stronger financial and competitive position. Termination of sections 406 and 419 subsidies in 1985 and 1988 will also affect commuter airline profits and service to as many as 100 small communities. These service reductions could, in turn, contribute to an offsetting increase in business aviation.

- *Strike Impacts.*—Traffic restrictions imposed by FAA as a result of the PATCO strike will continue for at least 2 years and possibly far longer. FAA assumes that traffic will rebound rapidly when these restriction are removed, but adjustments made by users during this period may permanently alter aviation growth trends and traffic distribution. Observers have pointed out that the General Aviation Reservation system has artifically forced into the IFR system many GA operations that might otherwise have been outside the system—Visual Flight Rules (VFR)—and these users may have become accustomed to using ATC services. Others feel that airport slot allocation has helped major air carriers while hindering the expansion of commuters and new entrants. These traffic restrictions—particularly at major hubs—might have to be extended or reimposed in the future as a means of addressing airport congestion and encouraging further redistribution of operations to relievers and second-tier hubs.

*Braniff International ceased operations on May 12, 1982, and filed for voluntary bankruptcy under ch. 11. It has 120 days to formulate a reorganization plan acceptable to its creditors.

SPECIFIC TECHNOLOGIES

The current ATC system, both in en route centers and terminal areas, is based on the technology of the 1960's. Technology has made rapid strides since that time, and virtually everyone believes that the present ATC system should be upgraded or replaced. New computer hardware, software, and communications technologies can be used to build an ATC system that is safer, more reliable, and more cost effective.

The program of improvements proposed in the 1982 NAS Plan are technologically feasible and desirable for purposes of safety, capacity, and productivity. The foregoing analysis of FAA's traffic forecasts, however, raises questions about how soon additional capacity will be required. Furthermore, in some cases there are technological alternatives that might serve the ends of safety and productivity as well or better, and possibly at less cost, than those proposed by FAA. These alternatives merit reexamination; but, given the long leadtimes required for the modernization program proposed by FAA, the choices need to be studied without delay so that decisions can be reached promptly.

SYSTEM DESIGN AND TRANSITION

A key element in the 1982 NAS Plan is merger of the present 23 en route centers and 188 terminal control facilities into a total of 60 or fewer consolidated ATC facilities. There are differences in ATC requirements between en route and terminal environments, but they are not so significant that separate and distinct systems must be maintained. Consolidation would also allow FAA to use common hardware and software to support all ATC activities, rather than maintaining separate but functionally similar systems as at present. If this also allows a move toward standard, "off the shelf" equipment, FAA could be in a position to move with the technology as it develops in the future. Producers of computer and communication equipment are generally committed to providing their customers with "family" systems that can evolve to take advantage of new technologies as they become available.

FAA has chosen to move from the present ATC system to the new one in a series of incremental stages, minimizing the amount of change at each point in the transition. The FAA Administrator has stated that this approach minimizes risk by limiting the number of system components affected by a given change. Many of the participants in OTA's general conference approved of this conservative approach, but others pointed out that there is no risk-free way to go from the current system to a new one. Though each step of the FAA incremental approach involves some risk, the overall technological risk is likely to be lower than if the change were made in a more dramatic way. Unfortunately, such incremental change introduces the possibility of an entirely different kind of risk—that the hardware choices made in the first stages might limit the options available for the final system design. The future architecture of the system, in short, may be constrained by the obsolete architecture of the system it replaces. This is of particular concern with regard to computer replacement, the first step in the plan.

Several experts have suggested that the needs of the system would be better served if FAA kept the present system running to meet short-term needs, thus making it possible to design and deploy an entirely new system to meet the long-term needs of the future. Advocates of this "clean-sheet" approach agree emphatically with other experts that the present system must be replaced, and that the first steps in this process should be undertaken as soon as possible. However, they also point out that any equipment acquired in the short term would probably have to be modified, replaced, or augmented with other computers when the new system is deployed in the 1990's. Thus, they advocate decoupling short-term remedial measures from long-term replacement by finding a cost-effective way to shore up the present system with the intent of discarding it alto-

gether when the new system comes on line. The chief advantage of the "clean-sheet" approach is that it would allow new system hardware and software to be designed in an integrated fashion, without either being constrained by the need for compatibility with the computer system now in place.

EN ROUTE COMPUTER REPLACEMENT

FAA's plan for implementing the new en route ATC system consists of four steps: 1) "rehosting" the existing software in a new central processor that "emulates" the present IBM 9020 but has greater capacity; 2) replacing the present display units used by controllers with new "sector suites" compatible with the current software but containing sufficient processing capacity to assume some ATC functions; 3) concurrent with step 2, discarding the current software for new software capable of taking advantage of the new sector suites and (if possible) compatible with the "host" hardware; and 4) implementing a number of advanced functions designed to enhance the overall performance of the ATC system. OTA's review indicates that, in general, this is a reasonable approach, but there are questions about the separation of hardware replacement from software redesign and about FAA's reasons for selecting this approach over others that were considered.

The current IBM 9020 computers are unique to FAA: none are in service elsewhere, and no machine now in production is capable of running the NAS software. FAA believes it has anticipated the potential problems of rehosting this software, and several vendors have indicated that they have acceptable solutions. Participants in OTA's technical Working Group No. 2 indicated, however, that moving the existing software to a new machine, no matter how similar to the 9020, is more difficult than FAA indicates in the Plan. The task can be done, given sufficient time and money, but the schedule proposed by FAA is probably optimistic.

FAA believes that the host computer will serve as the hardware element of the ultimate system. However, they do allow for the possibility that it may have to be supplemented or replaced in the 1990's with yet another new computer to accommodate the new system software. Some experts feel that budgetary constraints might lead FAA to retain the first host computer, however, even though it proved less than ideal for the new system. Others insist that the host computer should be considered a "throwaway" and that the design of the future system should not be constrained by the requirement to incorporate the host computer selected now as an interim remedial measure.

In January 1982, FAA submitted to Congress an analysis of technological options for replacing the en route computer system.[2] One of the options examined was replacing 9020As with 9020Ds at 10 sites as a near-term measure to assure adequate capacity until a replacement system is designed and deployed. FAA's analysis showed that this option would give all 20 en route centers sufficient capacity to accommodate anticipated growth until 1996, well after the new system is scheduled to be deployed. FAA has demonstrated the feasibility of this approach in replacing a 9020A with a 9020D system at the Jacksonville center, and the option analysis report indicates that such an upgrade could be effected at other centers. FAA estimates that upgrading 10 installations from As to Ds could be completed by 1984 at a cost of $64 million; installing a new host computer at all 20 en route centers (as outlined in the NAS Plan) could be completed by 1986 at a cost of about $250 million. On several other points of comparison—such as technological risk, constraint on future system design, and impact on FAA's management resources—the FAA's January option analysis showed A-to-D upgrade to be superior to rehosting (see table 2).

Some participants in OTA's technical working group and general conference indicated that, based on FAA's own analysis, the A-to-D upgrade

[2]Federal Aviation Administration, op. cit.

Table 2.—Comparison of Rehosting and Upgrading 9020As to 9020Ds

	Rehosting	A-to-D upgrade
Description	Rehost present software on new computer, then replace software and add additional processors needed for advanced system.	Upgrade 9020A computers to 9020D at 10 centers, then replace hardware and software in a single step, and finally upgrade computer to advanced system.
FAA evaluation:		
Schedule	Computer replacement 1986 Software replacement 1990 Full advanced system 1992	Computer upgrade 1984 New computer and software 1989 Full advanced system 1993
Cost of first step	$250 million	$64 million
Total cost	$1.39 billion	$1.39 billion
Risk	Rehost may constrain future system	Low
Impact on FAA resources	High	Medium
Ability to evolve	Medium	Unconstrained
Transition impact	High	Medium

SOURCE: Federal Aviation Administration, "Response to Congressional Recommendations Regarding the FAA's En Route Air Traffic Control Computer System," DOT/FAA/AAP-82-3, January 1982.

option is the one that should have been selected. It offers quick relief from capacity problems at precisely the centers that now or will have problems, with lower risks, and at a lower cost. It also preserves the opportunity to undertake the overall design of a new system unencumbered by the shortcomings of a computer capable of rehosting the existing software. This option, they added, was more conducive to both innovation and competition in the procurement of the new system. A former senior IBM executive who was intimately involved in the development of the 9020 computers, told OTA that there would be few problems in converting existing 360/65s to 9020s.* FAA reports and FAA representatives attending the OTA conference have expressed similar opinions.

An FAA observer at the OTA conference explained that one reason for rejecting the A to D upgrade alternative was that the agency could not locate a sufficient number of IBM 360/65s to carry out upgrading at 10 centers. OTA subsequently made inquiries of dealers in used computers and was assured that there would be little difficulty in acquiring 35 IBM 360/65 systems over the next 6 months to a year. An inquiry to the General Services Administration showed a total of 103 IBM 360/65s in the Federal computer inventory as of April 6, 1982. Of these, 13 have been declared surplus and may be useable; many others are undoubtedly used in routine data-processing applications where they could easily be replaced with more modern equipment. Such an exchange would bring an immediate benefit to the Government, because the IBM 360/65 is no longer a cost-effective machine at many installations, yet good use could be made of it in the ATC application where there is now no satisfactory alternative.

FAA sources have also raised questions about the long-term maintainability of the 9020, but the agency's January 1982 report to the Senate indicated that maintainability has not been a problem and is not anticipated to become one during the remainder of the decade. IBM will not supply parts for 9020 series after 1984, but this gives FAA 2 years to determine its future maintenance needs and stockpile sufficient spare parts to last until the new system is deployed.

Statements made by FAA since the NAS Plan was released* indicate that the choice of the rehost approach was based on four major considerations:

*The 9020D system, which is a multiprocessor design unique to FAA, is a derivative of IBM 360 series computers. Three-quarters or more of the constituent parts of a 9020D are 360/65 components; the remainder consists of parts from other IBM system 360 computers (notably the 360/67 model) plus some specially manufactured assemblies. The central processing element of the 9020D, for example, is essentially three specially modified 360/65s. To replace 9020A computers with 9020D computers at 10 centers would therefore involve acquisition and modification of 30 IBM 360/65s.

*Including remarks at the OTA conference and comments on the preliminary draft of this report.

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1. *Ability to meet capacity needs projected for the late 1980's.*—The FAA report to Congress in January 1982 asserted that A-to-D upgrade would also allow the projected demand for services to be met through the mid-1990's, or later if the demand materializes more slowly than expected.
2. *Improved reliability and maintainability.*—The reliability of the 9020 system appears to be more a problem of software than hardware, and since the present software would be retained, neither approach would alleviate this problem. Further, FAA has stated that, with or without rehosting, it plans to procure sufficient spare parts to keep the 9020s operating satisfactorily until the new computer system comes on line at the end of this decade.
3. *Ability to support productivity increases planned under the automated en route ATC system (AERA).*—The planned productivity increases to be realized from AERA will result mainly from software improvements not hardware changes; but, in any event, AERA will not be implemented until the early 1990's when the new computer system would be in place under either option.
4. *Reduced developmental risk.*—The incremental rehost approach reduces some kinds of developmental risk but—as argued above—it introduces another kind of risk, namely that hardware choices made in the first stages might limit the options available for the final system design.

In short, OTA does not find these reasons—either individually or collectively—to be persuasive arguments in favor of rehosting. OTA agrees that efforts for eventual replacement of the present system need to be pursued as vigorously and as rapidly as possible. However, FAA has not presented convincing evidence that the selected approach—rehosting—is in fact superior to other alternatives. This is not to argue that rehosting is unworkable or ill-advised. Rather, the point is that FAA has not made a persuasive case and that FAA should present a direct and detailed comparison of rehosting, A-to-D upgrading, and any other options the FAA considers workable. This justification is indispensable to an informed congressional review of the proposed computer replacement strategy. Such a head-to-head comparison of alternatives need not delay the overall schedule of the NAS Plan, and it could even advance the objectives of the Plan by providing a basis for clear understanding at the outset on where FAA is headed and how it proposes to get there.

AUTOMATION AND HUMAN FACTORS

The present ATC system is very labor-intensive and, without significant increases in controller productivity, the cost of operating the ATC system could rise precipitously as traffic grows. The number of aircraft that a controller team can handle with the present system is limited, and the conventional solution to handling a larger volume of traffic—decreasing sector size—has practical limits. FAA looks to increased automation as the principal means of achieving higher levels of controller productivity.

AERA, which is scheduled to be implemented in the early 1990's, would change the role of the controller from that of an active participant in the control process to that of a manager who oversees the operation of a highly automated system. Many of the routine decisionmaking functions now performed by humans would be automated, with the result that fewer controllers will be required for a given level of traffic. Elements of AERA are now undergoing testing, and some features will be added to the existing en route software after it has been rehosted. Other functions—those that will have the greatest impact on the role of the controller and the character of the ATC system—will not be implemented until the early part of the next decade when the redesigned software has been installed. It is this latter group of functions that may require either enhancement or replacement of the proposed host computer in the 1990's (see above).

As envisioned by FAA, AERA is designed to increase the efficiency of airspace utilization as well as the productivity of controllers. AERA will also enable users to follow more fuel-efficient flight paths and make better use of the equipment they are now installing on their aircraft. Flight management and navigation computers, linked to AERA by a new communication link (Mode S), will eventually receive and respond to flight instructions without increasing aircrew workload. Similarly, delays in the system will be minimized by the flow control procedures, and safety will be enhanced because the system will provide for the separation of IFR from VFR traffic outside terminal areas, rather than providing separation only between IFR aircraft as is now the case.

Human factors and safety are important concerns in AERA. In a highly automated system it might be impossible to revert to manual control in the event of a system failure. Therefore, the AERA concept assumes that the functions of the future ATC system will be distributed among various elements. In the event that the main computer at an ATC facility fails, the sector suite (acquired during the second phase of system modernization) will contain enough processing power to provide at least some backup functions; other functions will be transferred in real time to neighboring centers that remain operational.

FAA has yet to refine the AERA concept completely. The distribution of functions among the various computer resources has not yet been determined, nor have the respective roles of human controllers and automated systems been defined. This task will be carried out by FAA and the contractor responsible for the design of the new system.

This point is stressed by the critics of the rehosting approach to computer replacement and those who suggest that FAA use a "clean sheet" approach to the system design. They argue that premature acquisition of host hardware for the short term could limit the options of the system design contractor in the long term. This could result in a requirement for extensive and expensive modifications of the host computers, a second wholesale computer replacement, or (since that seems unlikely) the implementation of a system that cannot take full advantage of the available technologies and design options. None of the critics suggest that replacement be deferred, and all of them recognize that at some point FAA must commit to a specific design even though there will always be a better technology available at some point in the future. Rather, their concern is that premature commitment to "rehosting" hardware could limit FAA's ability to take advantage of the best technology that is now available.

Studies of the AERA concept commissioned by FAA have generally agreed that the proposed approach is feasible. However, one study, recently completed by the Rand Corp., suggests that the AERA concept may not be sound.[3] The Rand study indicates that total commitment to automation, with the controller no longer an active part of the system, is unwarranted and could present safety problems. It suggests that the controller will not be sufficiently involved in the traffic situation to detect errors in the system and analyze them in time to take effective action. As an alternative to the AERA concept, Rand suggests a "shared control" concept in which the controller has a more active part in the control process. In the end, the level of automation proposed by Rand would be very close to that proposed under AERA, although the route to achieve that level would be different and it might not achieve the increases in productivity that would result from the implementation of the FAA plan.

FAA, on the other hand, argues that it would not be possible to achieve the incremental improvements required for the shared-control approach, and that the automated system is expected to be more reliable than a system in which human controllers are active participants. FAA maintains it would be basically unsound, beyond a point, to back up an automated system with a human one that is less reliable.

[3]Robert Wesson, et al., "Scenarios for Evolution of Air Traffic Control," The Rand Corp., R-2698-FAA, November 1981.

COMMUNICATION

Communication is the backbone of air traffic control. Instructions and information vital to the safety of flight must be communicated between ground and air and between ATC facilities on the ground. While the present requirement for air-to-air communication is minimal, this link may assume greater importance in the future.

In the proposed plan, FAA indicates that a new data link (Mode S) will be the primary channel for transmitting data from the ground to the air and between aircraft in flight.* Mode S will be necessary to support the automated ATC system that FAA proposes for the future and for the distribution of weather information and other data of interest to aircraft in flight. It may also be used to collect weather observations from appropriately instrumented aircraft as part of the real-time weather system envisioned by FAA. This data link will also be used in TCAS, the collision avoidance system adopted by FAA, to coordinate the maneuvers of aircraft when a possible conflict is detected.

*At the OTA conference, a representative of FAA outlined the differences between Mode S and the Discrete Address Beacon System (DABS) concept from which it was derived. From the point of view of the data link, Mode S and DABS are functionally equivalent. However, the ground facility requirement for Mode S will be considerably less costly because it does not involve transmitting maneuver instructions to aircraft to resolve conflicts or avoid collisions. This also means that less computer power and less complex software will be required to handle Mode S than would have been required to handle DABS. Mode S has nevertheless been the subject of controversy, primarily due to GA concern over the costs and airspace restrictions that would be imposed by eventual mandatory equipage (see "Impacts on Airspace Users").

Use of this data link will require installation of Mode S transponders on aircraft. These transponders are also intended to improve the quality of the surveillance data available to the ATC system. FAA plans to extend the requirement for Mode S equipage to all instrument flights above 6,000 ft by the end of the century, compared to 12,500 ft for the present Mode C. However, FAA expects that most aircraft will have equipped voluntarily by that time, because of the enhanced services that will be available only to aircraft carrying Mode S transponders. Roughly three-fourths of the current civilian fleet is equipped with the present Air Traffic Control Radar Beacon System (ATCRBS) transponders, although only half this number has the more advanced Mode C altitude encoder.

Communication between ATC facilities on the ground is also vital to the operation of the system, particularly as the level of automation increases. The 1982 NAS Plan envisions a dedicated system to handle these communications requirements. It was difficult to assess FAA's proposals because of a lack of details in the 1982 NAS Plan, but Working Group No. 2 questioned the need for a dedicated system. Despite the existing Federal investment in equipment and rights of way, several participants felt that, given the current state-of-the-art, FAA could meet its requirements by procuring needed communication services on the open market.

COLLISION AVOIDANCE

The debate over collision-avoidance systems has gone on for over 20 years. Collision-avoidance systems are designed to back up the separation assurance services provided by FAA and to resolve conflicts that may occur because of system errors. They are not designed to function as a substitute for the basic separation assurance services supplied by ground control facilities.

During the summer of 1981, FAA adopted the Traffic Alert Collision Avoidance System (TCAS) as the collision avoidance system to be implemented, and it has been labeled by the Administrator as a key element of the 1982 NAS Plan. TCAS is a totally airborne system that requires virtually no expenditures by FAA beyond those for the Mode S data link, which TCAS uses to

coordinate maneuvers between aircraft. Initially, at least, installation of the required avionics will be voluntary on the part of the users.

There are two variants of TCAS. TCAS I, intended for installation in small GA aircraft at minimal cost, provides information regarding the presence of "intruder" aircraft and could be upgraded to include a display of traffic advisories on potentially conflicting TCAS II aircraft. TCAS II, designed for airliners and business aircraft, is a more comprehensive system that provides a display of relative bearing and distance and presentation of a climb or descend indicator for an avoidance maneuver. There are engineering models of both TCAS systems, although neither is presently ready for certification and deployment. The value of TCAS I has been challenged, since it indicates only the presence of another aircraft without providing data as to its relative position. The feasibility of TCAS II has also been challenged. The present working model of TCAS II provides only a rather coarse indication of relative bearing, and the high-resolution directional antenna required for a more accurate and useful TCAS II system remains in the early stages of development. Several participants in the OTA conference suggested that this antenna might not be available for some time.

Representatives of the military community expressed concern to OTA about the impact of TCAS on the military fleet, particularly on high-performance tactical aircraft. They point out that space in these aircraft is at a premium, particularly for the installation of avionics that do not enhance mission capabilities or low-altitude safety. They would therefore seek a Mode S design that can be integrated with a military system such as JTIDS or IFF. They also point out that the installation of the antennas required for TCAS II could adversely affect the aerodynamic performance of tactical aircraft. FAA representatives have suggested that the military may not be required by the FAA to install TCAS (see "Impacts on Airspace Users").

SATELLITE TECHNOLOGIES

Participants in OTA's technical working group pointed out that FAA has given very little attention to the possible role of satellites in the ATC system. This technology has developed rapidly over the past few years, and satellites have considerable potential not only as a communications resource but also for use in surveillance and navigation.

FAA does envision that satellites could eventually have a role in providing ATC services to aircraft operating over land, but the agency believes they are not yet a cost-effective alternative to ground-based systems. There is considerably greater potential in the short term for using satellites to provide services to aircraft operating over large bodies of water, where only minimal services are now available.

Satellites also have the potential for improving low-altitude surveillance. There are presently no proposals to extend coverage to the ground, but the possibility of providing this level of coverage at some point in the future does exist. The area covered by a ground-based sensor is limited by terrain, and it would be very expensive to provide for full coverage of U.S. airspace using ground sensors alone. While surveillance radars would not be mounted on satellites, ATC computers could use the Mode S data link to request position reports and provide properly equipped aircraft with separation services. This would be particularly useful in resolving the problems that arise when high-speed military aircraft on operational training missions must share low-altitude airspace with small GA aircraft.

Satellites also have considerable potential as aids to navigation. The military Global Positioning Satellite system is partially deployed and, when completed, could be used to provide navigational fixes with the same level of accuracy now afforded ground-based navigation aids. While national security considerations might limit the precision of the navigation aid provided to civil avia-

tion, FAA omitted navigation satellites from the 1982 NAS Plan on the basis of timing. The preparatory work necessary to bring civil services to an operational status could not be completed before the end of the present decade, when FAA plans to have the essential parts of the new ATC system in place. Slippages in FAA's proposed deployment schedules, however, could reopen the satellite option.

IMPACTS ON AIRSPACE USERS

FAA is attempting to modernize an ATC system that is nearing the upper limit of its productivity. New computer capacity and a higher level of automation should enhance the system's ability to deliver air traffic control services to those suitably equipped. In the longer term, the AERA functions will greatly ease the management of long-distance, high-altitude, point-to-point flights. Air carriers and larger business aircraft will benefit most directly from system improvements in the NAS plan. Military and some GA users, who may often fly VFR for short distances or at low altitudes will also receive benefits, but they are mixed with drawbacks as well.

The plan is written from the perspective of a ground-based manager of the airspace. As a "user" of its own system, FAA should gain a number of benefits from automating and consolidating the ATC system. Of the new functions to be added to the en route and terminal area computers, nearly all are designed to provide better information to the controller or to relieve him of routine chores. Thus, these functions will enable the FAA to do its job—provide for safe, expeditious use of the airspace—more efficiently.

If automation and consolidation work as planned, FAA will receive greatly increased productivity from controllers and maintenance personnel. FAA expects this will lead to an actual decrease in the controller workforce and a leveling of operating and maintenance costs, despite increased demand for services. It is generally agreed that modernization will lead to avoidance of the costs of maintaining the aging system into the indefinite future. However, FAA has not yet made available their basis for projecting increases in productivity. Some observers note that the introduction of NAS Stage A automation in the early 1970's, while it did slow the growth rate of the controller work force, did not live up to FAA's expectations in this regard.

Users who are properly equipped and who operate at certain altitudes will begin receiving direct benefits from the planned AERA enhancements early in the next decade. FAA expects fuel-efficient route planning to save users $250 million per year. Most of these benefits would accrue to air carriers and business aviation because of their high fuel use. In terms of more efficient operation, these two user groups are likely to benefit most from the full range of AERA improvements.

GENERAL AVIATION

With 214,000 aircraft, the GA fleet is two orders of magnitude larger than the commercial fleet (2,541). Some 79 percent of the GA fleet are single-engine aircraft, most of which rarely fly under IFR. The automation of Flight Service Stations is expected to provide benefits to GA users—notably, improved weather information. Small aircraft operating under VFR would probably utilize few of the other new ATC services.

The plan states that after 1990, aircraft will have to be equipped with Mode S transponders to fly above 12,500 ft. After 2000, transponders would be required above 6,000 ft in order to receive ATC services.

For the majority of the GA fleet, operating under VFR, the transponders will serve only to mark their positions electronically. They will not receive the other services available to IFR aircraft. Though the 1982 NAS Plan makes the decision to equip voluntary, the GA pilot who does not have a transponder will find the volume of the airspace available to him becoming smaller. Altitude restrictions will, according to some GA representatives, force many fliers that would prefer VFR to fly IFR in order to avoid delays and unattractive routings or to gain access to more airports.

Owners of GA aircraft who wish to make full use of the ATC system may want to equip with TCAS and Microwave Landing System (MLS) avionics. The cost of this equipment will not be onerous for owners of multiengine business aircraft, who are generally eager to modernize their

airborne electronics and avail themselves of the full range of ATC services. However, the single-engine operator would get a relatively small return for an avionics investment that might cost several thousand dollars.

DEPARTMENT OF DEFENSE

The Department of Defense (DOD) is both a major user and joint administrator of the national airspace. Yet, the 1982 NAS Plan appears to have been developed without prior consultation with DOD. Concern has been expressed about the effect of planned FAA actions on the interface between military and civil ATC systems. In addition, some of the improved services that FAA plans to provide may either be irrelevant to the military mission or impose more costs than benefits on the military users.

DOD controls a significant amount of the airspace. DOD's 8,000 controllers and 231 ATC facilities handle civil as well as military traffic in their sectors, and their role has increased since last summer's PATCO strike. The NAS Plan does not make clear how future upgrading and consolidation of centers and communications facilities will affect the military role or the required compatibility between military and civil ATC systems.

The military forces also have the responsibility to defend from airborne intrusion. Some FAA-owned primary radars are used for this purpose by DOD under a joint surveillance system. FAA plans to phase out these primary radars by 2000, when most of the domestic fleet is expected to be equipped with Mode S transponders. However, primary radars will still be needed for defense surveillance, and the manner of their replacement is not made clear in the proposed plan.

Military aviation accounts for about 20 percent of all ATC operations in the continental United States. (This includes ATC services provided by military facilities for civil as well as military aircraft.) Although the percentage of this traffic handled by FAA en route centers is small (16 percent) on average, it is substantial in some regions. For example, military flights account for 46 percent of en route handles at the Albuquerque center. The high concentration of military flights in certain regions makes it necessary for FAA to coordinate carefully with the military, since any planned relocation of bases or training areas could greatly affect FAA's projection of future traffic volume at selected centers.

Military use of domestic airspace is mainly for training missions, not point-to-point transportation. This means that high-performance aircraft sometimes operate at low altitudes, sharing airspace with slow-moving GA aircraft operating under VFR. See-and-avoid procedures do not work well in these circumstances, and a recent Air Force survey found that 87 percent of reported near-collisions occurred at altitudes below 7,500 ft in uncontrolled airspace. At present, Flight Service Stations (FSS) advise GA pilots of military activity only on request, and there is no indication in the plan that an improvement of this procedure is planned as part of FSS automation. Future FAA plans to put a "floor" of 6,000 ft on secondary surveillance radar mean that problems of separating military and GA traffic at low altitudes will continue into the future. Some means to provide radar coverage down to 1,000 or 2,000 ft would allow more military flights to operate under IFR and to rely on ATC for separation from VFR traffic.

FAA's plans for secondary surveillance radar depend on aircraft being equipped with Mode S transponders. The military services have reservations about this new avionics equipment because it is of doubtful value to the military. Although TCAS might have value in warning military aircraft of the proximity of other TCAS-equipped aircraft, it will be of no value in protecting against unequipped aircraft, as many small GA aircraft at low altitude are likely to be. The Mode S transponder would offer some advantage to military aircraft when they operate under IFR in the domestic airspace, but it would in no way improve their combat capability.

DOD estimates the cost to equip military aircraft with Mode S alone will exceed $1 billion. These costs, which will ultimately be borne by the general taxpayer, must be balanced against whatever benefits Mode S has for the civil system. Costs to equip military aircraft with TCAS will also be high. Further, TCAS has little military utility, and concern has been expressed that the TCAS antenna could actually interfere with the aerodynamic performance of certain tactical aircraft.

COST AND FUNDING ISSUES

The costs of implementing the 1982 NAS Plan over the next 5 years would lead to substantial increases in the FAA budget for facilities and equipment (F&E) and research, engineering, and development (RE&D). According to budget estimates supplied by FAA and OMB, the F&E costs for the period fiscal year 1983 to fiscal year 1987 would amount to about $5.2 billion (constant 1982 dollars). The RE&D costs would be $942 million (see table 3).

Table 3.—FAA Budget Estimates, Fiscal Years 1983-87

Budget category	Funding by fiscal year (in millions of dollars)[a]					
	1983	1984	1985	1986	1987	1983-87
Facilities and equipment	725	1,393	1,407	1,271	1,270	6,066
	(684)	(1,252)	(1,207)	(1,022)	(1,022)	(5,187)
Research, engineering, and development	134	256	269	204	204	1,097
	(126)	(257)	(231)	(164)	(164)	(942)
Airport aid	450	450	450	450	450	2,250
	(425)	(404)	(386)	(361)	(361)	(1,937)
Operation and maintenance	2,550	2,578	2,627	2,677	2,727	13,159
	(2,406)	(2,316)	(2,254)	(2,168)	(2,168)	(11,312)
All other	45	53	53	53	53	257
	(42)	(48)	(45)	(43)	(43)	(220)
Total	3,904	4,760	4,806	4,655	4,704	22,829
	(3,683)	(4,277)	(4,123)	(3,758)	(3,757)	(19,598)

[a]The first figures listed are current dollars; those beneath in parenthesis are 1982 constant dollars based on FAA-assumed inflation rates of 5.7 percent in fiscal year 1983, 4.7 percent in fiscal year 1984, 4.6 percent in fiscal year 1985, and 3.5 percent in fiscal years 1986 and 1987.

SOURCE: FAA and OMB budget estimates.

A comparison of these projected costs, on an annualized basis, with those of the period fiscal years 1971-80 is shown in table 4. Future F&E costs would be slightly over twice the historical level, in constant-dollar terms; and RE&D costs would be 50 percent higher. Cost estimates for the NAS Plan in the years beyond 1987 have not yet been released by FAA, but it seems likely that annual expenditures of roughly equal magnitude would be needed through the early 1990's in order to complete modernization of the ATC system, install a new communication network, and upgrade air navigation facilities.

Table 4.—Past and Future FAA Expenditures

	Average annual expenditures (millions of dollars)	
	Actual 1971-80[a]	Projected 1983-87[b]
Facilities and equipment	463	1,038
Research, engineering, and development	124	188
Airport aid (ADAP)	673	387
Operation and maintenance	2,564	2,263
All other	62	44
Total	3,886	3,920

[a]Based on FAA appropriations for fiscal years 1971 to 1980, converted to constant 1982 dollars.
[b]Based on FAA and OMB estimates.

USER FEES

Although the NAS Plan does not address matters of funding directly, subsequent statements by the administration tie implementation of the Plan very closely to funding issues. FAA Administrator Helms has indicated that the success of the Plan depends heavily upon securing a long-term funding commitment at the outset. The proposed method of assuring a stable and reliable source of funds is a system of user fees that would recover 85 percent of the FAA's future capital and operating costs from those who receive ATC services. This proposal is based on the general view of the

administration that beneficiaries of Government services should pay the costs incurred in providing those services.

In essence, the system of user fees proposed by the administration would reestablish the excise taxes that were levied on airspace users under the Airport and Airway Development Act of 1970, which expired at the end of fiscal year 1980. The current proposal would reauthorize revenue deposits to the Airport and Airway Trust Fund and institute the following user fees:

- 8 percent passenger ticket tax;
- 5 percent freight waybill tax;
- $3.00 international departure tax;
- general aviation gasoline tax of 12¢/gallon for fiscal year 1982-83 and rising thereafter at 2¢/year until reaching 20¢/gallon in fiscal year 1987; and
- general aviation jet fuel tax of 14¢/gallon for fiscal year 1982-83 rising at 2¢/year to 22¢/gallon by 1987.

Initial OMB estimates, published in February 1982, indicated that these tax schedules would lead, by 1987, to full recovery of the 85-percent share of FAA costs allocated to civil aviation.[4] Later figures released by FAA and OMB in April 1982 contained an increase of about $2 billion in projected FAA expenditures related to the NAS Plan for the period fiscal years 1983-87.[5] However, it was estimated that 85-percent cost recovery could still be achieved by the proposed taxes if coupled with a drawdown of about $2.2 billion from the uncommitted balance in the Airport and Airways Trust Fund (table 5).

[4] *Major Themes and Additional Budget Details, FY 1983* (Washington, D.C.: Office of Management and Budget, Feb. 8, 1982), pp. 228-229.

[5] Estimates presented by FAA Administrator Helms to the Transportation Subcommittee of the House Committee on Appropriations, Apr. 20, 1982.

Table 5.—FAA Budget and Cost Recovery, Fiscal Years 1983-87

	Current dollars by fiscal years (in millions)					
	1983	1984	1985	1986	1987	1983-87
Budget authority[a]	3,904	4,760	4,806	4,655	4,704	22,829
User fee revenues:[b]						
Current law	1,474	1,670	1,878	2,108	2,344	9,474
Proposed increases	1,187	1,350	1,548	1,742	1,946	7,773
Total	2,661	3,020	3,426	3,850	4,290	17,247
Trust Fund drawdown	657	1,026	659	107	(292)[c]	2,157
Cost recovery (percent):						
Current law	38	35	39	45	50	41
With proposed increases	68	63	71	83	91	75
With trust fund drawdown (return)	85	85	85	85	85	85

SOURCES: [a]FAA and OMB estimates presented to Transportation Subcommittee, House Committee on Appropriations, Apr. 20, 1982.
[b]OMB, "Major Themes and Additional Budget Details, Fiscal Year 1983," February 1982.
[c]Return to Trust Fund.

COST ALLOCATION

A more detailed analysis of the cost recovery from proposed user fees (shown in table 6) indicates that the burden of costs recovered would not fall equally on each class of airspace user. The costs recovered from air carriers through the passenger ticket tax, international departure tax, and freight waybill tax would vary from 104 to 148 percent of the share of costs allocated to them by FAA. The proportion recovered from GA users would be between 12 and 20 percent of their allocated share. Thus, GA would receive a substantial cross-subsidy from airline passengers and shippers of air freight. Within GA, the principal beneficiaries of this cross-subsidy would be that part

Table 6.—Cost Recovery Under the Administration's Proposed User Fees
(in millions of dollars)

	Fiscal year					
	1983	1984	1985	1986	1987	1983-87
Air carrier share (58 percent of FAA costs):						
Allocated share under FAA-proposed budget	2,264	2,761	2,787	2,700	2,728	13,240
Revenue under proposed user fees[a]	2,530	2,863	3,237	3,631	4,035	16,296
Cost recovery (percent)	112	104	116	134	148	123
General aviation share (27 percent of FAA costs):						
Allocated share under FAA-proposed budget	1,054	1,285	1,298	1,257	1,270	6,164
Revenue under proposed user fees[b]	131	157	189	219	255	951
Cost recovery (percent)	12	12	15	17	20	15
Total cost recovery from civil aviation (percent)	68	63	71	83	91	76

[a]Made up of 8 percent ticket tax (air carriers and commuters), 5 percent freight waybill tax, and $3 international departure tax.
[b]Made up of taxes on gasoline and jet fuel.

SOURCES: OMB, "Major Themes and Additional Budget Details, Fiscal Year 1983," February 1982. FAA estimates presented to Transportation Subcommittee, House Committee on Appropriation, Apr. 20, 1982.

of the business and corporate aircraft fleet consisting of turboprop and turbojet aircraft. These aircraft, which now number about 7,600, or twice the air carrier fleet, operate in the ATC system much of the time and are used in a manner similar to air carriers—point-to-point flights, into and out of major airports, under IFR, and receiving full ATC services. The business and corporate aircraft segment now constitutes about 60 percent of all GA traffic that uses the IFR system and represents 30 to 35 percent of the total workload at FAA towers and en route centers. By the early 1990's, FAA projects that GA turboprops and turbojets will make up about 45 percent of the ATC facility workload. (Air carriers will make up 30 percent, other GA 15 percent, and military 10 percent.)

The administration advocates full recovery of allocated costs from each class of airspace user as a principle of taxation. However, even allowing for the imprecision of the methodology of cost allocation and revenue projection, the user fees proposed by the administration do not accomplish parity of cost recovery. A passenger ticket tax of 6.5 percent, not the proposed 8 percent, would be sufficient to produce full recovery of the commercial aviation share. For GA to pay a share roughly proportionate to the burden it places on FAA facilities, the combined gasoline and jet fuel taxes would have to be five to six times higher than the current administration proposal. Organizations of general aircraft owners and manufacturers point out that such an increase, even if phased in over several years, would have a severely depressing effect on the use and purchase of GA aircraft.

The administration's proposal is likely to be contested by airspace users on several grounds. First, there is strong disagreement by civil aviation groups about what share of FAA costs should be allocated to users and what share should be treated as a general public benefit. Their contention is that the 85-percent share allocated to users is excessive because the public benefit of the National Airspace System is much higher than 15 percent—perhaps more on the order of 20 to 30 percent if one includes the general benefits of the air transportation system. Thus, they would argue for cost recovery from civil users of roughly 70 to 75 percent of FAA costs—not the 85 percent assumed in the current administration proposal.

Second, there is also dispute about the allocation of costs between commercial and general aviation. The owners and operators of small propellor aircraft weighing under 12,500 lb contend that

they make very little use of the IFR system and therefore should be charged only for the lesser services they receive under VFR.* The 1978 cost allocation study by FAA took the small aircraft owners' position into account and offered an alternative cost allocation scheme (called the "minimum services method") that reduced the overall GA share to 13 percent with the balance allocated to the general public as society's cost of maintaining a safe national airspace system.[6]

While business and corporate aircraft operators generally oppose the concept of differential taxation based on their more extensive use of the IFR system, it is precisely this small percentage of the GA fleet that is responsible for the largest projected increase in the demand for ATC services. The turbine-powered portion of the GA fleet, virtually all of which are flown for business purposes, is forecast by FAA to grow from 7,600 to 15,700 planes by 1993. The growth of business aviation activity is primarily responsible for GA projections of near-term capacity problems at en route centers.

If equitable cost recovery is to be the principle, a cost allocation formula should take into account significant differences in the burden placed on the ATC system by the various segments of the GA fleet. The administration proposal does not do so, except that the tax on jet fuel is 2¢/gallon higher than the tax on aviation gasoline. In selecting the proposed scheme, the administration seems to be hewing close to the system of taxation that existed under the previous Airport and Airway Development Act, taxes which are familiar and generally acceptable to the civil aviation community. The alternative of seeking to resolve the issue of cost recovery in a more equitable, but less familiar way, would likely make the administration's proposed user fees even more controversial.

*The Aircraft Owners and Pilots Association, for instance, estimates that only 5 percent of the GA flights are under IFR and that the average flight time for GA aircraft that do fly IFR is roughly 30 minutes, compared with 1 hour 23 minutes for air carriers.

[6]*Financing the Airport and Airway System: Cost Allocation and Recovery*, FAA-AVP-78-14 (Washington, D.C.: Federal Aviation Administration, November 1978).

ALTERNATIVE METHODS OF TAXATION

Other methods of levying user charges are possible: either fees based on the actual use made of the ATC system or an annual tax based on aircraft characteristics and avionics equipment.[7]

Participants in the OTA Conference on the National Airspace System Plan flatly ruled out direct user charges as unworkable. OTA does not agree. By means of the present ATCRBS transponder it is possible to identify uniquely each aircraft using the ATC system, continuously monitoring each plane from takeoff to landing. This capability would be enhanced by the future Mode S transponder. The data generated by either of these transponder systems could provide the Government with a detailed record of the services received by each aircraft. Owners could then be billed for what they used.

Toll roads provide a rough analogy. Charges on those highways are usually based on the distance traveled and the number of axles on the vehicle, a factor which approximates the burden placed on the road surface by vehicle weight. Data generated by the ATCRBS or Mode S transponders could conceivably provide the FAA with a record of the time each transponder-equipped aircraft is in the system. From that information, FAA might develop a basis for "toll charges" and collections. Computers now make it possible for persons to make a call from any of the 170 million telephones in the United States and to pay for the charges on their own phone bill a month later. Social Security mails monthly checks to over 35 million recipients, either directly or to their banks. So, before some form of direct billing is completely ruled out, FAA should determine whether the modern technology of transponders and computers could be utilized to make direct user fees a practical alternative to excise taxes.

Another possible mechanism for levying user charges is a yearly tax on aircraft by weight, number of engines, or avionics equipment. The price

[7]These alternatives are discussed in ch. 7 of the OTA report, *Aircraft and Air Traffic Control System*, OTA-STI-175, January 1982.

of admission to the future ATC System will be sophisticated avionics (Mode S, TCAS, MLS) to complement the ground-based sytem. Taxing that equipment could provide FAA with an alternative means of financing ATC services.

While the idea merits further inquiry, there are at least two concerns to be overcome. First, a tax on avionics equipment would not be a tax on avionics use. The charge would be the same whether an airplane flew 200 or 2,000 hours a year and whether it used the advanced equipment or not. From the user's point of view, there would be no direct link between services received and taxes paid. Still, it is not unreasonable to assume that aircraft carrying certain avionics will make use of that equipment to receive ATC services and, hence, that a tax on avionics would be an economically efficient way to recover the costs of providing services.

Another concern, voiced by several OTA conferees, is that raising the price of admission to the ATC system could have a negative effect on safety. The new avionics equipment is designed to make flying safer, and FAA hopes to induce GA owners to equip voluntarily by offering them more and better services. For example, weather is a factor in about 40 percent of all fatal aircraft accidents, and the Mode S data link is intended to bring automated and improved weather information to GA pilots who are equipped with these transponders. A tax that discourages avionics purchases could conceivably weaken the NAS Plan's principal goal: safety.

OTHER FUNDING ISSUES

There are several other issues that arise from the proposed user fees: the negative effect of fees on aviation growth, the disbursement of user revenues to cover operating and maintenance costs, and the disposition of the present uncommitted balance in the Airport and Airway Trust Fund.

The FAA's growth forecasts form an important part of FAA's justification for rapid modernization and expansion of the ATC system. Increased user fees, however, increase the price of commercial air travel and the costs to GA users. The effect of these cost increases could be to dampen the expected growth in civil aviation, perhaps by enough to alter significantly the forecast level of demand for services at FAA facilities. This, in turn, implies that ATC equipment and facilities to service this demand may not have to be as extensive as FAA expects or that they may not be needed as soon as now forecast. An analysis by FAA of the relationship between user fees and aviation growth would be a valuable aid to Congress in evaluating the proposed schedule for ATC system improvements.

The administration proposal calls for user fees to recover 85 percent of all FAA costs, including operation and maintenance (O&M) expenses, which make up about 60 percent of the FAA budget for the coming 5 years. In the past, airspace users have objected to funding O&M expenses through user fees on grounds that O&M costs include many items not directly attributable to operating the ATC system and that users should not be expected to bear these costs, which should be assigned to the general public. Figures ranging from 25 to 50 percent of O&M costs have been suggested by various user groups in the past as a reasonable upper limit of their proper share. Another objection, which pertains only to user fees collected under the previous Airport and Airway Development Act, is that use of Trust Fund revenues to cover O&M costs violates the basic purpose of that Act, which was to fund capital improvements to airports and airways. Some users, who have opposed diversion of Trust Fund monies to noncapital expenditures in the past, might oppose the current Administration proposal unless the share to be used for O&M costs were negotiated specifically and made contingent upon not reducing expenditures for capital purposes.

A third, and related, issue is how to spend the present uncommitted balance of roughly $3 billion in the Trust Fund. The administration proposal

is to draw down this balance over the next 5 years, using it to supplement user fees in order to meet 85 percent of FAA expenses in all budget categories. This is an integral part of the overall plan to put FAA funding on a base whereby users pay their full allocated share of all ATC system costs. On the other hand, aviation user groups argue that this would not be consistent with the purpose for which the Trust Fund was established.

PART 2

Appendixes

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Appendix A

GROWTH SCENARIOS IN FAA'S NATIONAL AIRSPACE SYSTEM PLAN

Members of Working Group 1 (February 25, 1982)

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Massachusetts Institute of Technology

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Fairchild Industries, Inc.

Herman Gilster
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David Lewis
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David J. McGowan
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Robert E. Monroe
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Barney Parrella
Manager, Airport Planning and Development
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Gilbert F. Quinby
Consultant

John Slowik
Vice President
Airline and Aerospace Department
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Summary

In its most recent (2/16/82) forecasts of aviation activity for the period 1982-93, the Federal Aviation Administration (FAA) projected substantial rates of growth in commercial and general aviation (GA) traffic, as well as a large increase in the size of the GA fleet. These projections undergird FAA's National Airspace System (NAS) Plan for modernizing the Nation's air traffic control (ATC) system and the timetable the agency would follow in making the NAS Plan a reality.

The Working Group spent much of the day discussing the adequacy of FAA's aviation forecasts. These discussions centered on: 1) the internal structure of FAA's econometric model, 2) its reliance on the Office of Management and Budget (OMB) forecasts of the gross national product (GNP) and other economic indicators, 3) its high level of aggregation, and 4) its omission of cyclical economic behavior. The consensus appeared to be that FAA's forecasting methods may tend to produce unduly optimistic projections of economic growth and its effects on aviation.

The group also looked into a number of related factors that could limit substantially the growth envisioned in the Plan. These included: 1) airport congestion; 2) user fees; and 3) financing of aircraft purchases.

The group generally agreed that modernization would be desirable for reasons of reliability and productivity alone. Their questions dealt not with the need for the proposed improvements, but with their timing. Slower growth would allow more time, and several participants noted that the choice of technology might also be affected by the timing of the NAS Plan. A few extra years could be important, since the system one could develop now might be significantly different from one designed later in the decade.

Discussion

On February 12, 1982, the FAA Office of Aviation Policy and Plans issued "FAA Forecasts on Aviation Activity, Fiscal Years 1982-1993." On the title page, FAA explicitly noted that its projections were "based on OMB's January 12, 1982, forecasts of economic variables."

Members of Working Group 1 were given a copy of that document at the outset of the meeting and referred to it often during the discussion of FAA's econometric model and the agency's use of the administration's economic projections.

The ideas expressed by the group during the meeting on February 25 fell into two major categories: 1) economic forecasts and 2) related factors of an economic and noneconomic nature that could affect FAA's forecasts for growth in aviation.

Economic Forecasts

The FAA Forecasting Model

David Lewis, an econometrician, with the Congressional Budget Office (CBO) led the discussion with an examination of FAA forecasts of aviation activity over the last 23 years. In comparing those projections with actual levels of activity, Lewis discerned three distinct chronological periods.

During 1959-65, FAA's 5-year projections for various measures of aviation activity and ATC workloads proved too low by an average of 18.7 percent. But the reverse of that pattern occurred during 1966-73. The agency's 5-year projections for that period were too high by an average of 32.5 percent.

In 1974 FAA shifted from trend extrapolation to an econometric model. While Lewis called this a step forward, he also suggested that the model might prove only marginally more accurate than past projections. According to his calculations, the average forecast error since 1974 has been high by 21.2 percent; the maximum error for any one year's forecasts was 34.7 percent too high. (Lewis' tables are attachment A-1.)

Lewis noted that "there's been an improvement in the projection of passenger demand on the air carrier side." But even though some of the 1976 projections for 1981 were not far off, the Professional Air Traffic Controllers Organization (PATCO) strike led air carriers "to ground small planes, resulting in improved load factors," he said. So, while FAA's forecasts for enplanements proved 4.3 percent too high, its estimate for domestic revenue passenger miles (RPMs) was 9.0 percent too low. The forecast for total tower operations, however, proved 34.7 percent too high.

Lewis raised this point not to criticize the FAA—which could not have anticipated the strike, he said—but to highlight "the importance of each factor in the forecasting chain."

FAA uses four variables in a linear formula to predict RPMs. Lewis argued that two of those variables, disposable personal income and consumer expenditure in transportation, "are highly related to each other." If that is so, he asked, "why are they *both* in here?"

With deregulation in 1978, the airlines went into what Barney Parrella, Air Transport Association, called a "shakedown period." Dr. Robert Simpson, of the Massachusetts Institute of Technology Flight Transportation Laboratory, pointed out that "200 or 300 years of transportation economics history tells us that the pricing activity is chaotic in an unregulated state. It always goes that way because in transportation you always have spare seats, spare capacity."

Yet, the econometric model FAA is using to project air carrier traffic into the 1990's does not take into account the fare wars and other competitive behavior that followed deregulation.

The model also does not incorporate possible changes in labor costs. Because of agreements signed before deregulation, the older airlines are locked into high wage and salary scales. "You can suspect a problem," said John Slowik of Citibank N.A., "when one major airline estimates it only needs 58 percent of employee-hours it now pays for. Or when the Civil Aeronautics Board's own data point out that certain majors' fully allocated costs are as much as 89 percent above a low-cost national carrier."

The driving factor in FAA estimates of the workload imposed by general aviation is the size of the GA fleet. This is a critically important calculation because rapid growth in the GA fleet accounts for the greatest proportion of projected needs in FAA's NAS Plan. Yet, the agency ignores fuel prices in calculating changes in fleet size. Lewis suggested, and Robert Monroe of the Aircraft Owners and Pilots Association confirmed, that fuel prices are an important factor in the size of the *active* GA fleet and in the total number of hours flown.

Monroe estimates, however, that 15 percent of the GA fleet is inactive, meaning that those planes have not flown during the past year. If FAA greatly overestimates the utilization as well as the size of the GA fleet, it would affect both the agency's projected workload and the Government's ability to finance the NAS Plan through user fees. Specifically, Federal revenue collections from higher taxes on aviation fuels could fall far short of current projections. That, in turn, could shift a greater portion of the burden of financing the NAS Plan from system users to the general fund.

Economic Variables

GNP and disposable personal income, two highly related economic factors, are the principal variables underlying FAA's calculations of air carrier and GA operations. FAA does not calculate these factors independently; they are derived from forecasts of economic variables prepared by the Executive Office of the President, OMB, as of January 1982. Monroe labeled these projections "a political forecast."

Several members observed that the administration's numbers could be called "targets" rather than forecasts. Slowik characterized them as "hockey-stick forecasts. They are kind of flat for a while, and they start going

up . . . because things are always getting better in the future."

The air carrier projections led Samuel C. Colwell, of Fairchild Industries, Inc., to ask: "What forces are going to cause (air) traffic growth . . . to go faster than it did in the '70s? Every force that I see, everything that I look at, says it has to grow slower . . . Fuel prices, even if they moderate . . . are still at least going to go up as fast as inflation and probably faster . . . There are productivity increases coming, but they're minor compared to the productivity increases we had" in the last two decades.

Another example of this phenomenon may be seen in Government projections for general aviation. FAA estimates that the GA share of instrument operations at airports will rise from 48 percent in 1982 to 55 percent in 1993. The urgency of the NAS Plan timetable is based largely on this expected boom in GA traffic.

The FAA forecasts that the size of the GA fleet will rise from 211,000 in 1981 to 332,900 by 1993. Yet, in 1980, according to FAA, the fleet grew by only 700 aircraft. Last year, it was estimated to have grown by 3,000 planes. Growth is projected to remain slow in 1982-83 but should then explode in the out years. Between 1985 and 1993, FAA expects the GA fleet to expand by over 12,000 aircraft per year.

Because the timing in the NAS Plan seems to hinge on the growth of the GA activity, the accuracy of its forecasts for that sector is critically important. Zalman Shavell of OTA suggested that "we need greater disaggregation" in the data FAA uses to forecast GA activity and other operations. After considering the data, assumptions, and projections that went into the agency's GA forecasts, other members of the group seemed somewhat skeptical of the results.

In projecting the size of the GA fleet, for instance, FAA assumes "an elasticity of 17, each 1-percent increase in GNP leading to a 17-percent increase in the change of the size of the fleet," Lewis pointed out. "They (FAA) take the aggregate forecasts and just make a guess at the share of the aggregate that will be held by" each type or category of GA aircraft, he said. "There is no attempt to forecast sets, those individual classes, from the bottom up."

Although GNP drives the agency's projections for GA activity, said Lewis, the model assumes that "there's a saturation level . . . that means at the margin, progressively higher levels of income lead to progressively smaller changes in the demand for aircraft."

Monroe questioned whether GNP should even be considered "a causal variable. It's always been my understanding that GNP was a consequence of doing something, not a cause of doing something . . . . If the airplane is indeed a business tool, then GNP is a consequence of buying and operating aircraft, not a causal factor."

Questions were also raised about the accuracy of FAA data on the present GA fleet. Consultant Gilbert F. Quinby found that Government recordkeepers "were very careless about purging accident aircraft out of the file." Monroe agreed, pointing out that "the difference between a sheet of paper and an airplane is where we get into trouble." He also noted that the Government does not have "a good system of purging" to account for aircraft that were exported.

After comparing past GA growth rates with current FAA projections, Monroe suggested that "the projection of numbers in the Plan is not out of the realm of possibility." That, however, seemed to be the extent of his optimism.

Indeed, he argued that the importance of GNP and disposable income may be overstated in FAA calculations. Alluding to the Vahovich study,[1] he noted that "convenience seems to be the primary problem with most aircraft owners. It's not the cost. That actually came fairly well down in the line of concerns, about fourth or fifth or sixth."

But in the final analysis FAA seems to have pegged its aviation forecasts to the administration's optimism about economic growth. "All these equations are driven by highly aggregate variables: GNP, consumer expenditure (on transportation and) disposable income," said Lewis. "They're very sensitive to those variables and changes in long-term growth rates. To the extent that those growth rates are too optimistic, the forecasts will be too optimistic as well."

Cyclical Economic Factors

Although the U.S. economy has made impressive gains at times, it seldom moves in a straight line. In recent years, it has gone through several periods of recession and recovery. Yet, FAA's forecasts through 1993 apparently ignore the possibility of cyclical fluctuations in the future. The agency assumes a steady upward march in GNP.

Some members of the group were skeptical of the forecasts for this reason. "Any trend-extrapolation model that is just used arbitrarily is going to generate results like this, and they're always going to be bad," said Colwell. "And I think they're making the same mistake now because we're in another basic structural

[1] S. G. Vahovich, *General Aviation: Hours Flown and Avionics Purchase Decisions*, FAA-AVP-78-9 (Washington, D.C.: U.S. Department of Transportation, Federal Aviation Administration, Office of Aviation Policy, May 1978).

change in the industry. And so, if FAA or whoever is using these models would then apply some logic and reasons and adjust the models appropriately—not just rely on the outcome—they would do much, much better."

The General Aviation Manufacturers Association (GAMA) has an understandable interest in estimating growth in the GA fleet. Yet when GAMA makes "forecasts of production, sales and deliveries (it) will only do it for one year in advance," said David McGowan of GAMA. "We have no idea what's going to happen 2, 3, 5, even 12 years down the road . . . . What they (FAA) are using, I don't know."

Using charts, Herman Gilster, of Boeing Commercial Airplane Co., showed how Boeing's projections of domestic RPMs for 1980 fluctuated widely from its initial estimates in 1968 to its final prediction in 1979. The actual figure in 1980 proved to be 268 billion RPMs, but the company's forecasts ranged from about 475 billion (1969) down to 250 billion (1975-76). (See attachment A-2.)

These fluctuations, said Gilster, suggest that when "growth is high, or things look well, you forecast high. And then if you get into a depression area, such as '74 and '75, you lower your forecast dramatically. (So,) I think there's a tendency to have your long-range forecast highly influenced by the short-term economic situation."

Cyclical changes have also lead Boeing to revise its forecast for 1985 from 700 billion RPMs (1971) down to 310 billion RMPs (1982). In comparing Boeing's projections with those of other firms in the industry, Gilster noted that "the engine manufacturers . . . have lower forecasts than the airframe manufacturers." But he also pointed out that the Boeing and FAA forecasts of the size of the U.S. commercial jet fleet in the year 2000 closely match. (See attachment A-2.)

The price of commercial airliners is another cyclical economic factor omitted from FAA's forecasting model.

U.S. air carriers, said Slowik, are suffering from a "serious over-capacity which has been fueled by back-to-back negative traffic-growth years." Without good profits, many airlines cannot afford to modernize their fleet. Yet, he remarked, "there is little doubt that those airlines who want to operate profitably must replace old, inefficient aircraft with new-generation equipment."

To get new aircraft, most companies will need to sell a portion of their current inventory. But the market for old aircraft is so depressed, said Colwell, that "the prices of corporate jets are now equivalent to a used (Boeing) 727. They are up to $6 to $8 million for a new, large corporate jet."

But if the market for airliners does bounce back, air carriers might find their benefits short-lived. "The doomsday scenario that I have," said Simpson, "is that the (new Boeing) 757s and 767s coming off the line" will have to compete against their 727s and other older aircraft "when all our Columbia Airs and the rest . . . start grabbing them and putting them into service again." And, he added, "unless you put the axe to some of those airplanes, they don't physically disappear. They are always going to come back."

If that scenario were to transpire, it could also set off a new wave of price competition which might further erode the profitability of U.S. air carriers.

Other Factors Affecting Future Growth

Airport Congestion

In chapter II of the NAS Plan, FAA acknowledges that "it is growth in major metropolitan areas (covered by the large and medium hub airport and reliever airport statistics) that causes special concern. These areas contain the largest concentration of aviation industry consumers, representing 90 percent of the air carrier enplanements and 40 percent of itinerant aircraft operations . . . Because of their high population density, increasing resistance to the adverse environmental impact of airport growth, and the expensive and difficult task of land acquisition for the enlargement of existing facilities or construction of new airports, expansion in these areas is nearly impossible."

This chapter, in Barney Parrella's view, shows that FAA realizes that "airport availability or capacity at airports will be the constraining factor, going out to the year 2000, in terms of growth in the system." Gilbert Quinby added that "One way to test the realism of doubling the (GA) fleet is to try to figure out where they're going to put them with the present trends in runways, tiedowns, etc."

Yet, FAA's econometric model is unconstrained. In the words of H. Clark Stroupe, of Booz-Allen & Hamilton, the forecast "assumes an open-ended supply of air transportation." Is it consistent, then, for FAA to take airport congestion into account as a constraining factor in air-traffic management but to ignore that congestion when forecasting air-traffic growth?

This question was addressed by several members of the group. Parrella argued that "when you hit that ceiling, which is places to land, that seems to me to be . . . the ultimate definer of what your forecast will look like." Later, he added: "We can project these numbers in a forecast and talk about growth scenarios . . . (but the) overriding constraint is capacity at the major air-

ports . . . I mean, are we talking about a forecast that is really expected to come about, or are we really talking about some kind of target?"

FAA projects that the number of airports in the NAS Plan will grow from 3,163 to 4,000 by the turn of the century. That projection was greeted skeptically by Monroe, who recalled that "when they first established a Federal airport aid program back in 1945, the intent was to develop . . . 6,500 (to) 7,500 airports throughout the Nation . . . Well, the last three or four times that they have published any plan, the number of airports included in the plan has always declined."

Several factors, including high real estate costs, are working to shrink the number of places where an airplane can land. Monroe cited the Los Angeles Basin as one area where public use airports are disappearing. He quoted FAA data showing that over 300 airports per year have been closed or abandoned since 1965.

Monroe believes that "convenience" has become more important than cost in an individual's decision to purchase a small plane. But when owners find that they cannot use major airports and are forced to drive long distances to use strips which provide considerably less service, they often give up flying. The result, according to Monroe, "is a terrific turnover . . . . Half the (GA) fleet turns over in terms of numbers of registrations." Lack of convenient airports could also constrain the growth of the GA fleet and GA operations. "Growth is going to be very slow," Monroe said, "until we solve the airplane-airport problem."

Constraints on airport growth appear inevitable. Citing his recent experience with Boston's Logan Airport, Simpson argued that "there is no limit on passengers at this airport. There are ways to handle the parking lot and some of the building problems at any of these airports." The real constraints stem from restrictions on aircraft noise and insufficient land for additional runways.

At Logan, said Simpson, "what we are arguing about is one little, short 3,800-foot runway to handle commuter airlines and the possibility of talking the FAA into some parallel approaches on runways that are only 1,500 feet apart. That is it. There is nothing you can do with money to help Boston-Logan, and if you think you are going to go somewhere else in the Boston area and put another airport down, you are not going to do that either."

User Fees

How will the United States pay for an improved ATC system? This seems certain to be one of the thornier questions Congress may have to face.

In the NAS Plan (page I-34), FAA indicates that the cost of upgrading the ATC system "will be borne by the user."

During the discussion of user fees, Paul Phelps of OTA pointed out that the latest FAA forecast assumes that "the Administration's user-tax schedule will be in effect on July 1, 1982, and that money will start going into the (aviation) trust fund." These revenues will come from taxes on passenger tickets and on aviation fuel. But the projection, he added, "does not reflect . . . the two-cent-a-year escalator on those gas taxes, which may be another reason why general aviation local operations and . . . tower operations are so high in the out years."

Because the price of fuel is a factor in FAA forecasts of GA activity, the agency's failure to take this fuel-tax escalator into account would tend to add an upward bias to its estimates of local GA operations and the projected workload of its Flight Service Stations, which are used primarily by GA aircraft. Monroe agreed that user taxes slowed GA growth in the 1970's.

Would increased user taxes exercise a similar restraining effect in the 1980's? And if the Government does not receive the expected revenues from these levies, how will it pay for these improvements to the system? Quinby suggested that the "economic consequences of total fleet and total (operations) much lower than this (traffic forecast) might call for a review of the funding forecast."

Cost allocation turned out to be equally thorny. There are, as Quinby noted, "a lot of up-front costs that this Plan asks for which are very difficult to allocate. Who should pick up the tab for increasing the productivity of the technical personnel that it takes to man the system? . . . Who should pick up the tab for changing from leased Bell System lines to (an FAA-owned) microwave?"

FAA expects general aviation to account for 75 percent of the increased demand on the system. Should GA user fees be raised in rough proportion to the demand GA will put on the system?

Quinby did not think so. "From a standpoint of cash flow, assets (and) payroll," he said, "the air carrier business is on the order of 10 times as big as the general aviation business."

Parrella took issue with "this ability-to-pay scenario," which "in this current difficult air carrier market is not just . . . a simple thing that one can assert anymore . . . . You can't just say . . . it's the deep-pocket industry. We've heard from the bankers that that's just not the case in this environment . . . . It's very inequitable to have cross-subsidization from one industry to the other."

Monroe argued that "only five percent, approximately, of general aviation flights make use of the IFR system."

"And yet," countered Gilster, "we have another statistic, which is that more than 60 percent of the flights in the system are general aviation."

As this exchange indicates, the group reached no consensus concerning either the impact of user fees on traffic growth or the appropriate level of user taxes each sector of aviation should, or could, bear.

Aircraft Financing

The FAA model for changes in the size of the GA fleet is driven principally by GNP. It is far less sensitive to aircraft prices and interest rates. That formula was criticized as too mechanistic as well as too highly aggregated. "Corporate operations are the fastest growing part of GA right now," said Shavell. Yet by lumping corporate aircraft with the smaller planes, which are used largely for personal flying, one could come up with an estimate of GA fleet size that "may be totally invalid because you've ignored the detail," he said.

Lacking detailed and disaggregated data, the group was unable to reach any conclusions about the issue of financing GA purchases.

For the air carriers, however, there are essentially "three primary sources of funds," said Slowik. They are: Commercial banks, equity-type securities and the long-term institutional market (mostly insurance companies). "There is also a long-term market through pension funds," he added, "but they generally have rules where they will not lend money to companies with less than a double-A bond rating, which excludes all the airlines automatically."

"The estimates made by several of the major airlines indicate net profits of $150 million to $200 million per year (each) will be necessary if their planned and already-ordered new-generation aircraft are to be financed," he said. So, many carriers may not be able to take delivery of airliners currently on order. Gilster confirmed that some of Boeing's deliveries are being renegotiated.

With Wall Street unreceptive to airline equities and the institutional market charging the airlines interest rates 1 or 2 percentage points higher than their other customers, the carriers have nowhere to turn but to the banks.

"There would be quite a few carriers that wouldn't be in business today if it weren't for the banks making substantial concessions and putting more money into them," said Slowik. At Citibank, he continued, "we have had to buy out banks, where Midwestern, regional-type banks have refused to go along with addition terms."

Many airlines do not actually own their aircraft; they lease them from Citibank and other financial institutions. This source of financing, Slowik cautioned, would be jeopardized by proposed changes in the lease provisions of the Tax Reform Act of 1981. Airlines may also be able to benefit from offshore capital. Two years ago, for instance, "the first Eurobond financing was arranged for a major airline," said Slowik.

Though a return to profitability could save many of the carriers, it would have to be a very robust recovery to save them all from bankruptcy. A bank that foreclosed on an airline today would not be able to get a very good price for the carrier's aircraft. So, the banks might decide to wait until the price of used aircraft climbs substantially before calling in their notes.

Alternatively, a bank could force the large carriers to liquidate a portion of their fleet to pay off their debts. In other words, said Slowik, "it wouldn't necessarily require them to go bankrupt to get the money."

Questions for Working Group 2

Near the close of the meeting, the group touched on some issues it would like to see Working Group 2 explore:

1. *If FAA's scenario of rapid growth is judged to be overly optimistic, can the Government prudently delay a decision to upgrade the ATC system?*

   Quinby characterized the present system as "a tired bunch of hardware (that is) trying to run software with band-aids on it. It was designed to be shut down every night for maintenance, and it is not being shut down every night . . . When it breaks, the lack of redundancy and distributed-processing capability hurts them."
2. *How integrated are the various components of FAA's NAS Plan?*

   From his reading of the Plan, Monroe concluded that "the elements are so interconnected and . . . interdependent that you almost have to make the decision at the beginning to go the whole 10 yards . . . and, hence, it is not subject to . . . modification at any major part by any short-term alternations in forecasts."

   But Stroupe expressed a "hope that any new technology would have flexibility to make mid-course corrections towards demand in the 10- and 15-year timeframe."

3. *Would the choice of technology be likely to change if more time were available before the improvements would be needed?*

   "Well, quite frankly," said Stroupe, "a 2- or 3-year error in some of the saturation points is a significant difference in what type of technology and what type of system you might consider feasible to implement . . . You may open up alternatives if the number to saturation is 8 years instead of 4."
4. *Specifically, which of the options rejected by FAA might prove to be superior alternatives if growth were slower than expected and more time were available before capacity improvements had to be in place? (See Response to Congressional Recommendations Regarding FAA's En Route ATC Computer System,* DOT/FAA/AAP-82-3, January 1982.)

Questions for Staff Investigation

The Working Group also raised several issues that might be addressed by OTA staff, possibly in cooperation with the General Accounting Office (GAO) or CBO:

1. *To what extent are the scope and timing of FAA's plans driven by the need to accommodate growing demand, as opposed to the need to replace obsolescent equipment or to increase productivity?*
2. *How reasonable and consistent are FAA's aviation forecasts, with regard to procedures and economic assumptions as well as specific projections, and do they provide a satisfactory basis for FAA's long-range plans?*
3. *Specifically, how does FAA arrive at its forecasts of workloads and capacity constraints at individual en route centers, which seem so vital to the timing of its NAS Plan?*
4. *How accurately do FAA's forecasts reflect the potential impact of aviation user fees, and what effect will lower rates of traffic growth have on the revenues with which to pay for the proposed improvements?*

ATTACHMENT A-1: CBO ANALYSIS OF FAA FORECAST ACCURACY AND MODEL

Table A-1-1.—Five-Year Aviation Activity Forecasts Compared With Outturn (percent difference)

Forecast made in	For the year	Commercial air carriers enplanements	Revenue passenger miles	Hours flown in general aviation	All itinerant operations	Total operations
1959	1964	− 1.3	− 6.5	− 0.6	6.0	9.7
1960	1965	− 9.5	− 9.7	− 1.2	−12.7	−21.6
1961	1966	−27.5	−26.0	−15.3	−20.0	−28.9
1962	1967	−32.1	−31.4	−23.6	−20.6	−27.3
1963	1968	−41.3	−41.3	N/A	−26.9	−32.5
1964	1969	−31.4	−33.6	−23.5	−24.0	−24.9
1965	1970	−14.1	−19.8	−16.3	− 8.0	− 5.2
1966	1971	9.4	0.5	− 1.6	32.4	42.2
1967	1972	23.6	13.0	9.1	43.8	54.9
1968	1973	23.9	15.9	7.4	49.7	58.4
1969	1974	21.1	21.2	4.6	37.7	42.4
1970	1975	26.3	33.0	− 0.6	19.7	25.9
1971	1976	19.0	28.6	− 0.6	14.1	22.9
1972	1977	22.3	33.7	− 6.8	1.2	4.5
1973	1978	14.0	18.3	−10.4	2.3	8.8
1974	1979	−10.1	− 7.2	− 9.5	6.4	12.8
1975	1980	1.6	−14.7	− 1.2	11.3	16.0
1976	1981	4.3	− 9.0	15.7	25.7	34.7

SOURCE: David Lewis, Congressional Budget Office, from FAA Aviation Forecasts, 1959 to 1976.

Table A-1-2.—Summary of Forecast Periods

Period	Method	Performance 5 years ahead[a]	Environment
1959-65	Trend forecasting: unspecified links to economy, business cycle, population, fares, competition from other modes.	Average error −18.7% Worst year −32.5%	Expanding, prosperous economy. Rapidly growing population. Declining first-class and coach fares, (declining unit costs because of increasing use of jets).
1966-73	Trend forecasting: unspecified links to economy, business cycle, population, fares, competition from other modes.	Average error +32.5% Worst year +58.4%	Softening trends in aviation activity. Increasing ticket taxes, rising fares. Forecasts made in 1969 (published January 1970) assumed 4.25 percent growth rate in fiscal 1973, to continue at that rate through decade. Inflation 2 percent per year from fiscal year 1973. Fares projected to decline in real terms (flat in current dollars).
1974-onwards	Linear econometric models.	Average error +21.2% Worst year +34.7%	

[a]Operations forecasts.

SOURCE: David Lewis, Congressional Budget Office.

Table A-1-3.—FAA Forecasting Models

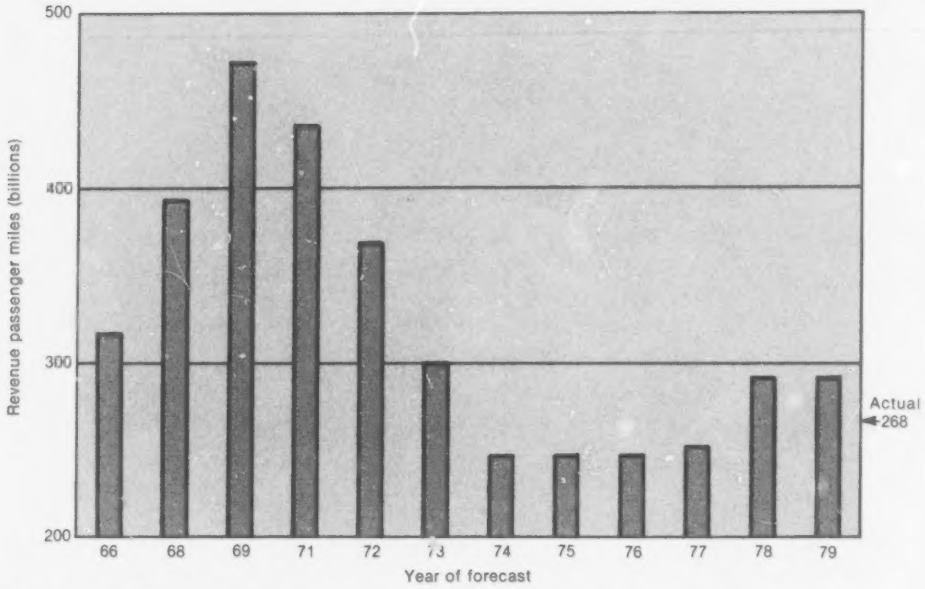
Measure	Model form	Causal variables	Elasticity (at mean)
Air carrier operations			
Revenue passenger miles (RPMs)	Linear econometric	Revenue per passenger mile	− 0.64
		Consumer expenditure in transportation	0.15
		Disposable income	1.80
		Investment in transportation	0.26
Total domestic operations	RPM × 2		
	Load factor × Average seating capacity × Average stage length	N/A	N/A
General aviation			
Tower workload:			
Change in fleet size	Linear semilog	GNP	17.00
		Aircraft price	− 4.00
		Interest rates	− 2.00
		Sales	3.00
		Time	Negative
Itinerant operations	Linear	Fleet size	1.07
		Fuel price	− 0.23
Local operations	Linear	Fleet size	0.21
		Students	1.00
Instrument operations	Linear	Fleet size	1.50
Flight service station workload:			
Aircraft contacted	Linear	Itinerant operations	1.10
Pilot briefs	Linear	Fleet size	1.60
		Fuel price	− 0.30
VFR flight plans	Linear	Fleet size	0.60
		Fuel price	− 0.27
IFR flight plans	Linear	Fleet size	1.60
		Fuel price	− 0.21

N/A - Not applicable.

SOURCE: David Lewis, Congressional Budget Office.

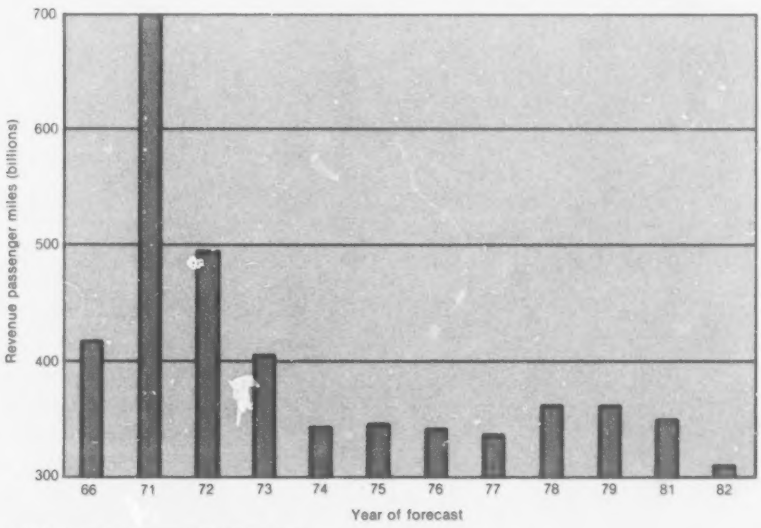
ATTACHMENT A-2: COMPARISON OF FAA FORECASTS WITH INDUSTRY FORECASTS (BOEING COMMERCIAL AIRPLANE CO.)

Figure A-2-1.—Forecasts of 1980 Domestic Air Traffic, 1966-79



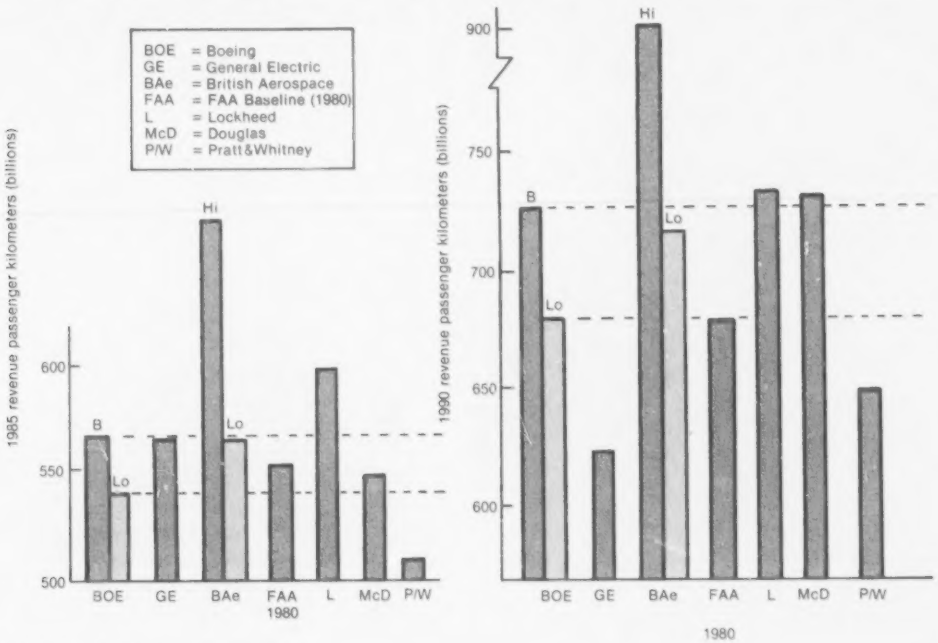
SOURCE: Boeing Commercial Airplane Co.

Figure A-2-2.—Forecasts of 1985 Domestic Air Traffic, 1966-82



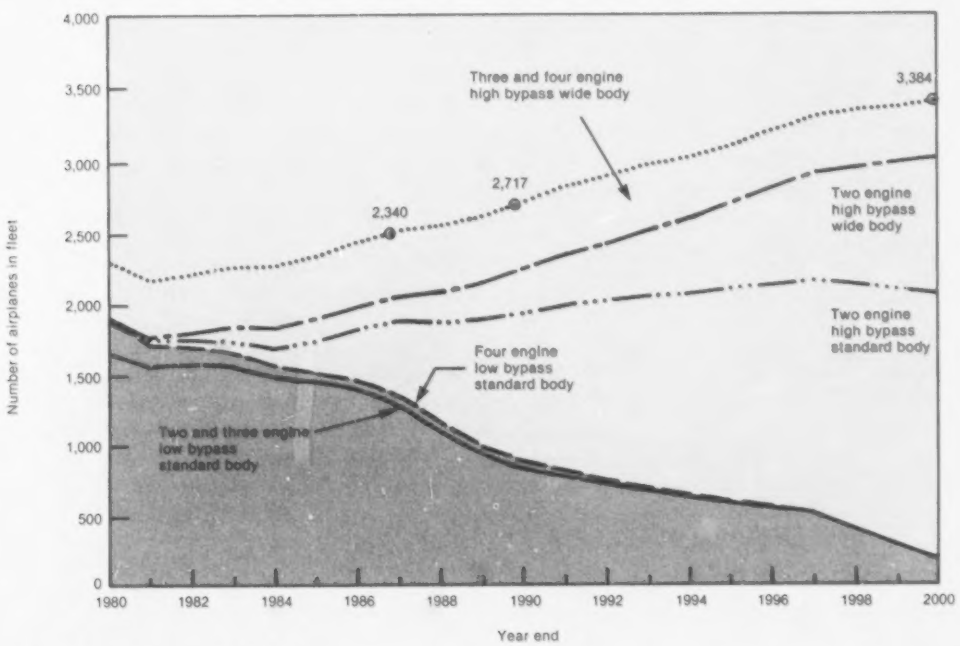
SOURCE: Boeing Commercial Airplane Co.

Figure A-2-3.—Comparison of Industry Forecasts of Domestic Air Traffic in 1985 and 1990



SOURCE: Boeing Commercial Airplane Co.

Figure A-2-4.—Market Forecast for U.S. Commercial Jet Passenger Fleet, 1980-2000


Number of airplanes in fleet
Three and four engine high bypass wide body
3,384
2,717
2,340
Two engine high bypass wide body
Two engine high bypass standard body
Four engine low bypass standard body
Two and three engine low bypass standard body
Year end

SOURCE: Boeing Commercial Airplane Co.

Appendix B

COMPUTER AND COMMUNICATION TECHNOLOGIES IN FAA'S NATIONAL AIRSPACE SYSTEM PLAN

Members of Working Group 2 (March 9, 1982)

H. Clark Stroupe, *Chairman*
Vice President, Booz-Allen & Hamilton, Inc.

Michael J. Ball
U.S. Air Force

Paul Baran
President, Cable Data Associates

W. W. Buchanan
Senior Associate, SES

James Burrows
Director, Institute for Computer Science and Technology

Anthony Csicseri
General Accounting Office

George Litchford
President, Litchford Electronics

Gilbert Quinby
Consultant

Harrison Rowe
Bell Laboratories, Crawford Hill Laboratory

Robert W. Simpson (Chairman, Working Group 1)
Professor, Flight Transportation Laboratory
Massachusetts Institute of Technology

Willis Ware
The Rand Corp.

Other Participants

John Andelin, OTA
Neal Blake, FAA
M. Karen Gamble, OTA
Sam Hale, OTA
Valerio Hunt, FAA
Larry L. Jenney, OTA
William Mills, OTA
Peter J. Ognibene, consultant to OTA
Paul B. Phelps, OTA
Zalman Shavell, OTA
Norman Solat, FAA
David Traynham, Subcommittee on Aviation of the House Committee on Public Works and Transportation

Summary

In its National Airspace System (NAS) Plan made public in January, the Federal Aviation Administration (FAA) outlined its proposals for modernizing the Nation's air traffic control (ATC) system.

Working Group 2 commended the NAS Plan as a worthwhile statement of goals and an advance over previous plans. However, the panel also suggested that FAA may have underestimated both the technological risks inherent in individual elements of the Plan and the scheduling risks involved in implementing and integrating these elements into a highly automated system. In general, the participants felt that there was sufficient uncertainty in FAA's traffic forecasts to require greater flexibility in its implementation schedule, particularly for the en route computer replacement.

While the group agreed that improvements are needed, most members were skeptical of FAA's plan to "rehost" the current en route software in a new mainframe computer. Because that software, too, will eventually be replaced, some suggested that the interim rehosting step could be bypassed. By upgrading 9020A computers to 9020Ds, FAA could increase its computational capacity sufficiently to postpone congestion at any en route center until the mid-1990's. This would give FAA additional time to benefit from improved software and the distributed architecture of modern computer hardware.

The group also indicated that the lack of a clear description of system architecture made it difficult to judge the details of computer and communications system design. Members also suggested that FAA devote additional attention to satellite-based systems for communication, navigation, and surveillance, as well as the impact of greater automation on those who use the ATC system.

Though the word "National" is in the title, the group noted that the NAS Plan is structurally incomplete. It largely excludes military aircraft and ATC facilities,

as well as the majority of the general aviation (GA) fleet which operates under Visual Flight Rules (VFR). Some participants also questioned whether the sharp distinction between "controlled" and "uncontrolled" airspace can be maintained in the future.

The Plan

Working Group 2 agreed that the Nation's ATC system needs to be modernized, despite their questions on technology and timing. In an observation that reflected the group's thinking, Chairman H. Clark Stroupe, vice president of Booz-Allen & Hamilton, Inc., said, "No one . . . has seriously entertained the concept of doing nothing." The group also had general praise for FAA's 1982 NAS Plan, which the agency made public in January. Consultant Gilbert F. Quinby felt it was "to be commended at a policy level," and Stroupe called it "a fairly significant set of goals, even bold in some sense, compared to some of the previous plans FAA has had." Other participants echoed these overall evaluations.

The choice of technologies was generally considered to be well within the state-of-the-art, although there was disagreement about specific components. George Litchford, president of Litchford Electronics, commented that, "As far as using the new technology (goes), I think it's being used in a conservative sense. In aviation you can't plunge ahead with brand new technology. You usually have to use quite well-proven technology, and I think in that sense it's a fairly conservative plan."

Others felt the Plan might be too conservative. "I looked at the technology," said Paul Baran, President of Cable Data Associates, "and it looked very, very old . . . . There seems to be a slight mismatch there between what we're able to do and what we're proposing to do." W. W. Buchanan, senior associate with SES, agreed. "Certainly the technology doesn't show an awful lot of advancement over the plans of 5 years ago or even 10 years ago," he said.

Several participants expressed apprehension, however, particularly when the discussion shifted from the individual technologies to the way they would be integrated and implemented by FAA. Dr. Willis Ware of The Rand Corp. put these concerns most strongly, saying "It's dripping with technical risk all over. About every third project talks casually about software. I would judge that most of those software remarks are not well-founded in terms of the resources needed to accomplish them. The en-route-control computer replacement I would regard as especially risky, primarily because of the software as it now exists in FAA. And they have a terrifying problem of how to get anywhere from where they are now." (See below under "Rehosting" and "Software and Sector Suites.")

In addition to its technological risks, the NAS Plan was also criticized for its omission of important elements of the aviation community, notably the armed services. "The military seems to be much more aware that they're part of the National Airspace System than FAA does in this planning document," said Stroupe. Litchford agreed, adding, "To FAA, it's like the military doesn't exist, and I think that's one of our major problems in all this documentation."

"The National Airspace System is defined in the FAA plan as an FAA system only," said Mike Ball of the Air Force, who represented the Department of Defense (DOD). It "doesn't address an architecture for the entire system because it leaves out the military-agency facilities. But beyond that, it's definitely not an airspace system plan because it doesn't address the overall needs of other people who are currently operating outside the IFR (Instrument Flight Rules) system." This includes most of the general aviation fleet, which FAA puts at 214,000 aircraft, whose operations are largely under VFR. (See below under "General Aviation.")

The group was also concerned about the haste with which FAA proposes to implement the NAS Plan. It was the consensus of Working Group 1 that FAA's traffic forecasts, based on last year's economic projections from the Office of Management and Budget (OMB), were unduly optimistic. Working Group 2 seemed equally skeptical of agency projections of an overloaded en route ATC system in the mid-1980's.

In addition, there were questions about the timing of the implementation schedule itself. The high level of automation in the NAS Plan involves "a whole new series of problems," according to Dr. James Burrows, director of the Institute for Computer Science and Technology. If one component falls behind schedule, it would send "ripples into everything else" in a way that "is not clear from looking at this book." Ware shared this view: "If anything slips, the whole thing slips."

Dr. Robert W. Simpson, professor, Flight Transportation Labs, MIT., who chaired Working Group 1, observed that, "One thing I'm sure of is that the forecasts are uncertain, and if I were planning a system this large I'd be planning it in such a way that I could accommodate it one way or the other." Ware agreed: "It (looks) like a logical sequence if you have no problems . . . (but) there's no plan for what happens if you have real problems."

Technologies

Rehosting

The group devoted a considerable amount of attention to FAA's decision to "rehost" the existing en route computer software in a larger mainframe computer, and only then replacing the trouble-plagued software itself. In an observation shared by many members of the group, Stroupe said, "I couldn't find the compelling reasons for a short-term rehosting approach to the computer (replacement) that seem to outweigh a lot of compelling reasons for a better long-term solution with more modern technology."

FAA spokesman Neal Blake explained that agency forecasts of air traffic growth were crucial in Administrator J. Lynn Helms's decision to rehost the ATC software in a new computer. "We clearly needed to get on with increasing the capacity of the air traffic control system in this decade, now in the late 1980's or early 1990's or beyond . . . . He (Helms) felt that we could not take on a program which had both hardware and software risks and be able to provide any near-term improvements in, say, the mid-1980's time-period."

Ware, who felt that the two-step computer replacement was "especially risky," reacted to Blake's argument by asserting that "the portability of software is mythology" and adding that "the system-design contractor (for phase two) will be constrained, for better or for worse, by the choice of the rehosting instrument or by whatever reasonable enhancement can be made in the host by upgrading within a family of computers."

Several members of the group then suggested that FAA might be able to skip the rehosting step entirely if it were willing to upgrade its present 9020 computers where necessary. FAA forecasts "operational delay days"* during the 1980's at only four en route centers, all of which use the 9020A computer. The 9020D, already installed at 10 centers, has 2.5 times the computational capacity of the A-model. FAA documents suggest that upgrading 9020A computers to D models would alleviate congestion at ATC centers until the mid-1900's. FAA has already successfully upgraded from 9020A to D in its Jacksonville center, and the complete engineering and data package resulting from this experience considerably reduces the technical risk of doing so at other centers.

In the shorter term, FAA might also be able to relieve en route congestion by redrawing the boundaries of certain ATC sectors. Zalman Shavell of OTA pointed out that the centers where congestion has been projected "are adjacent to areas covered by centers that have excess capacity." Ball suggested that "maybe the solution to this capacity problem is to bulge out your center boundaries" to alleviate congestion.

When asked if the agency had considered upgrading the affected A-models to D-models, Blake replied: "We looked at it, obviously . . . . I think the Administrator felt it was better to get a new system . . . we could build on . . . until we could get what we like . . . . The earlier we can get the new system in, the earlier we can start consolidating—saving people and saving money."

Buchanan agreed with Blake. "I am, perhaps, a little bit more uncomfortable with keeping the 9020s any longer than is absolutely necessary . . . . I would think it would be very important that FAA get some new, modern computer power at the earliest possible time."

Thi appeared to be a minority view, however. Baran's observation seemed closer to the group's general perception. "I wonder," he said, "whether it may pay for us just to start now working on the high-level (programing) language and go parallel with development of the computers, so when the time comes, we won't find ourselves implementing computer systems that are 5 or 10 years old to start with . . . . You either swallow a big pill now, or you're going to have to swallow a lot of pills the rest of the way."

Several members of the working group also expressed concern about FAA's strategy of awarding both contracts (new host and new software) at the same time. They raised the possibility that only one contractor, IBM, might be in a position to win them.

Burrows characterized the situation as "a procurement morass. It seems to me that when you start talking about replacing a 9020 and converting the current software, that is IBM . . . . Once you have emplaced IBM equipment as the follow-on equipment and talk about modifying that equipment to be compatible with the new software, . . . that is IBM again. So what they have . . . (is) a two-phase procurement which has guaranteed IBM in both of them."

Litchford agreed: "It is going to be hard for them to really solicit open, system bids before they select the whole." Anthony Csicseri of the General Accounting Office (GAO) added, however, that GAO had already informed FAA that the plan was subject to GSA procurement regulations requiring competitive acquisition, and that compliance "(would) not slow down the acquisition process needed to bring in a rehost system, if that's what's really required."

In the end, however, the issue of rehosting remained unresolved. "It looks to me," speculated Ware, "that what the Administrator has announced as a strategy

*Defined by FAA as a day when utilization of the 9020's processing capacity exceeds 80 percent of its available capacity for 1 hour or more.

is to get the money flowing, because he can't count on what the congressional attitude will be in 10 years . . . . Given the vagaries of how Government works and congressional funding, just the prudence of delaying a decision that might otherwise be sensible becomes questionable. So, therefore, it is really a judgment call."

Stroupe agreed. "It is a political and not a technical issue."

Software and Sector Suites

In his written presentation, FAA's Valerio Hunt indicated that "two major parallel efforts will be initiated . . . this summer. One of these efforts will be the procurement of a host computer that will possess the capability of executing the existing 9020 software. This strategy will provide the earliest increase in computer capability that can also be used as an integrated part of the total system repalcement . . . . The second parallel effort initially focuses on a total integrated system design for the entire system. This is followed by development of the new sector suite (of display terminals for controllers), a suitable data network, and the new software system."

Although Hunt as well as Blake characterized these programs as "parallel," they are not independent of each other because FAA expects its host computer will subsequently run the new system software. As a consequence, the hardware decision could have a considerable impact on software design and the functions assigned to the sector suites.

"The consolidation and integration of the terminals with the en route system seems very bold," said Stroupe, yet in examining the NAS Plan he found that "the whole partitioning and architecture of the system is not clear in many of the alternatives." Later, he asked: "has their proposal precluded going to any appropriate architecture for a very advanced, very automated system in the '90s?"

Ware replied that "your question is unanswerable because, in this document, there is no evidence of a system architecture . . . . It's the classical jurisdictional partition. The en-route centers are doing their upgrading. The communications guys are doing their upgrading. The Jacksonville center is doing its thing. There is no system architecture described in there."

When members of the group sought more details on the architecture of the new ATC system, Blake indicated that the agency has placed most of the burden of system integration on the contractors who will provide FAA with the elements of its new ATC system. "The vendor will deliver us an operating system which includes the hardware with whatever modifications he feels are proper ones for his machine . . . So he is delivering us, really, a turnkey system . . . . We will assume that in this decade we cannot build a perfect hardware-software package and that we will have to operate at the sector-processor level during certain types of failure . . . . The system contractor delivers a set of sector suites suitable for terminal and en route operations and tower operations. He delivers a new software package which includes all of the functions that were resident in the 9020s plus direct-route capability, which are the first steps of the AERA (Automated En Route Air Traffic Control) program."

Ware characterized this development and procurement strategy as "kind of a neat gambit," one that "pushes a lot of risk off FAA and onto those vendors."

Communications

In his presentation to the group, FAA's Norman Solat outlined the agency's planned changes in the ATC communications systems. Several participants had indicated that this aspect of FAA's proposal was difficult to assess because of the lack of detail in the NAS Plan.

They also questioned Solat's conclusion that the agency's investment in the existing communication system precludes major change or the substitution of a radically different technology. Solat pointed out: "What we have got at the facilities are the rights of way and the equipment and the microwave links. They are already there and paid for and owned by the taxpayers."

Ware took issue with Solat on this point. "I would argue that communications technology is not an issue," he said. "Just go out and buy it . . . . How do people in the present world shove data around mixed with message traffic? Packet nets. Look at the world. That's the way it's going, and FAA's dedicated line (approach) is kaput."

Harrison Rowe of Bell Laboratories wondered about characteristics of the data transmissions that determined FAA's design of the communications portion of the NAS Plan. "The basic things that drive what goes on in communications are not spelled out here in enough detail to let you get an informed opinion about whether it makes sense or not," he said. "We haven't heard any of the technical details about this Mode-S (transponder) and the (air-ground) data link and how it is all going to work."

Rowe pointed out that the frequency of transponder interrogations can be of critical importance. If they occur infrequently, the Mode S system would be adequate. "But if all these people flying around are interrogating each other all the time, there may be a lot

of traffic going on up there. You wonder if that system is going to overload or if it's going to create interference hundreds of miles away."

Satellites

In "reading the communications part" of the NAS Plan, said Baran, "one has the feeling that you're reading papers maybe 20 years old. There is no appreciation for the satellite and what it means in communication systems." Litchford agreed. "Nowhere in the Plan," he said, "are they really looking at satellites seriously until after the year 2000."

Solat argued that it is not clear whether a satellite-based communication system is cost-effective for handling trunk message traffic in the ATC system. FAA now has 2,000 equivalent voice-grade circuits, and Solat envisioned that a satellite Earth station could serve as the distribution center for messages on those circuits. But, he added, "right now, because of the capacity and the loads that are on those circuits, we don't see that there is a major payoff."

DOD is also concerned, Ball noted, because FAA appears to have "summarily dismissed" the NAVSTAR satellite and the Global Positioning System (GPS) used by the armed forces. "The problem between the FAA and DOD is how much of the coding are we going to release to civil use," he said. "In other words, we can locate (aircraft) extremely accurately, but we don't necessarily want to give that capability to everybody in the world." He went on to say that the amount of coding proposed by DOD for release to civil aviation more than meets the navigational accuracy requirements for nonmilitary users of the airspace.

FAA, according to Litchford, "argues that you really can't get landing accuracies" with GPS. Stroupe took a different tack. "The fact that you can't use GPS to land an aircraft doesn't say you shouldn't use it to replace one-mile-accuracy radar."

User Impacts

Some participants felt that, in drafting the NAS Plan, FAA did not give sufficient attention to the needs of certain elements of the aviation community. The Plan focuses almost exclusively on how to achieve a highly automated form of control for IFR traffic, especially during the en route portion of flight. There does not appear to be adequate concern for VFR traffic or operations at low altitudes (under 6,000 ft).

Moreover, the plan is written almost wholly from the perspective of the ground-based air traffic controller. Litchford labelled the plan as "a controller's wish book. In other words, it is aimed at the controller himself; it doesn't talk about the user's needs."

Department of Defense

The military services account for about 20 percent of all domestic traffic and as much as 46 percent of operations at en route centers like Albuquerque. In addition, they must also protect the Nation from airborne intrusions and attacks. Nevertheless, DOD "was not consulted by FAA prior to the announcement of the plan," according to Ball. The NAS Plan, in his view, "essentially has been designed as an improvement to a point-to-point air transportation system. But the majority of DOD use of the national airspace is not point-to-point air transportation but, rather, training missions . . . and they are basically left out of the system."

That omission also seems to be reflected in the air traffic growth projections on which the NAS Plan was based. FAA's "definition of the system demand is misleading," according to Ball. FAA's "traffic count, which gives the military traffic as 4 percent, is based on (operations at) FAA towers only. But if we take a look at all the traffic that is controlled in the IFR air traffic control system in the CONUS (Continental United States), DOD accounts for about 20 percent of the traffic count." Much of this traffic (and a good bit of civilian traffic as well) is handled by DOD's 233 ATC facilities and nearly 8,000 controllers in CONUS.

DOD has cooperated with FAA to ease the effects of the controllers' strike by transferring "a good deal of our flight operations from demand on the FAA system or the FAA portions of the system to our own facilities," according to Ball. Moreover, DOD has "a large program under way to relocate most of the training areas . . . to get away from the (areas of) heavy civil air traffic and try to help out."

DOD is concerned that FAA's requirement for Mode-S transponders may cause an increase in military expenditures with no appreciable increase in benefits. "Cost estimates to equip DOD aircraft with Mode-S are in excess of a billion dollars," said Ball, "and we're not sure Congress wants us to spend that kind of money for something that doesn't enhance our warfighting capability."

While Mode S avionics may have no appreciable effect on the aerodynamic performance of commercial or GA aircraft, they could have an adverse impact on military aircraft. "There is great concern (at DOD) about sticking more black boxes and more displays and more antennas on high-performance fighter aircraft," said Ball. "From what we've heard about the

antennas that will be required for TCAS (Traffic Alert and Collision Avoidance System), we're going to lose operational capability on fighters and other high-performance aircraft."

On the broader question of airspace surveillance, FAA indicates that, in the future, it will rely less on primary radar to monitor air traffic. "We see an evolution toward a system that is more directly based on Mode-S," Blake told the group. "The plan says that by the year 2000 we hope to have pretty well dropped our dependence on primary radar for en route services. That is, the current ATC type or the joint type radar. And we will be using primary radar . . . primarily for weather detection."

FAA believes the ATC system will be able to maintain better surveillance over air traffic through secondary radar and Mode-S transponders. But what about aircraft not equipped with these beacons? Ball expressed concern about the implications of this basic change in the surveillance system. "The elimination of the surveillance capabilities by the year 2000 is acceptable if we feel that (there is) another means . . . of maintaining the air defense and air sovereignty missions of the Department of Defense."

Military training missions will also be affected by the shift to secondary radar. "Half of our low-level training routes right now are flown under Visual Flight Rules because we don't have adequate communications or surveillance from the FAA to operate under Instrument Flight Rules," said Ball. "There is concern about the validity of VFR when we have got an F-4 down at 300 feet, going at 500 knots. It is a bit difficult for him to see and avoid (other aircraft) or for the Piper to see and avoid him."

Ball carried this criticism one step further. "The military expends a lot of money and effort in providing to the FAA system information on the scheduling and actual use times of those routes, . . . but the whole thing is totally inefficient right now. The schedules are buried in a pile of messages that are still on a clipboard somewhere. There is no graphic display. The Flight Service Station guy is overworked, giving weather briefings and everything else. He is not required to give a mandatory briefing of military activities to the general aviation VFR pilot—only on request."

General Aviation

Even though the NAS Plan affirms freedom of access to the airspace as a basic right, FAA envisions a highly automated ATC system oriented toward operation of well-equipped aircraft flown by experienced pilots. Some segments of the GA fleet, notably turbine-powered business aircraft, are of this type and regularly use the ATC system, but most GA aircraft do not. Yet the NAS Plan devotes little attention to the 90 percent of GA operations that take place under VFR. The NAS Plan apparently assumes that the present distinction between "controlled" and "uncontrolled" airspace will continue far into the future, but if FAA projections of a greatly expanded GA fleet come to pass, the extent of positive control may have to be broadened considerably into uncontrolled areas where most VFR flights now occur.

Some participants did not think the difference between IFR and VFR, or between controlled and uncontrolled airspace, could be perpetuated indefinitely. One of them was Ware, who asked: "Does this plan provide a system which is a proper foundation for gracefully extending (air traffic control) . . . down to sea level?"

"That's an important issue," said Baran, on which FAA "punted . . . implying that we're going to have VFR forever . . . . I think a plan that covers the period through the end of the century should include the implications of that potential change." In the future, perhaps near the turn of the century, said Ball, "the Visual Flight Rules concept just will not work, and we'll have too many 'midairs,' and the American public will demand a total airspace system."

The direction charted by FAA for the ATC system will necessarily increase the cost of entry with the requirement for Mode-S transponders and other avionic equipment. "If one expects people to voluntarily equip with something, there has to be a benefit; there have to be services," said Blake. And in the future, he continued, "if you want to get the good ATC services, you will have to buy it. If you don't want them, that is your choice."

FAA forecasts indicate that significant growth in the size of the general aviation fleet will result in much greater demand on its ATC centers. Quinby took a mixed view of that projection. "The count of the active general aviation fleet that comes out of this forecast is substantially higher than what seems realistically attainable, hangarable, maintainable, manufacturable and so forth," he said. However, he also contended that "it's conceivable . . . that half of the total general aviation active airplanes will be routinely engaged in the ATC system" in the future. High-performance corporate aircraft, the heaviest GA users of ATC services, today comprise the fastest growing segment of the fleet.

Automation

The new ATC system would make more extensive use of computers and automated modes of operation to increase the productivity of controllers. FAA claims that, when hardware and software are operating,

higher productivity will lead to lower manning levels and significant cost savings.

"I was interested in the claims that are made for personnel savings," said Buchanan. "It seems that all of the actions, principally the automation phases of the project, claim substantial savings in personnel. One wonders if FAA has really considered, though, what kind of staffing enhancements they would have to have to adequately support (and maintain) . . . a considerably higher level of automation than they are accustomed to handling."

Burrows expressed similar concerns. "There are statements about how we are going to load up the people by adding more automation," he said, "and I was wondering whether we've done experiments to show that was true . . . or whether those were just faith statements, that somehow between here and there we'll figure out how to do that."

Simpson stressed the importance of "human interaction" with an automated control system, where much routine decisionmaking is done by computers. "It's not going to be just keyboarding and monitoring and watching the software do the work. (Ideally, it should) be the controller commanding that software to do what he wants it to do." No decision should be "made by other than a human being. The machine can present the decisions to him. He's got to pass it through his brains and say, yes, that's what we want, and pass it back to the machine . . . . Otherwise, the machine is controlling, and the controller is trying to keep up with the decisions the machine is making. I don't think we'll ever get to that position."

The Rand Corporation Report

The Rand Corp. recently released a report entitled "Scenarios for Evolution of Air Traffic Control" in which it takes issue with FAA's approach to automation in the AERA program. The Rand report was not discussed specifically by the group, since it was not available at the time of the meeting. However, the concerns about automation expressed by working group participants closely paralleled the findings of the Rand study (see attachment B-1).

Rand's principal conclusion is that the goal of full automation sought under AERA is a questionable research and development strategy that may present serious problems with regard to safety, efficiency, and increased productivity. An ATC system in which computers make most of the time-critical decisions in controlling aircraft, while the human operator serves in a managerial and back-up role, implies a needlessly complete and irrevocable commitment to automation.

Rand argues for an alternative approach, called "shared control," that would construct the future ATC system as a series of independently operable, serially deployable modules that would aid—not replace—the human controller and keep him routinely involved in the minute-to-minute operation of the system.

ATTACHMENT B-1: EXCERPT FROM "SCENARIOS FOR EVOLUTION OF AIR TRAFFIC CONTROL"[1]

VI. CONCLUSIONS

We have considered several alternative ATC futures, beginning with a Baseline case in which nothing beyond the most conservative R&D projects paid off. We have concluded that the approach of simply adding more and more controllers is ultimately counterproductive from a performance standpoint. We have examined the FAA's plan to use advanced computer science technology to construct a fully automated ATC system for application near the year 2000. The expected aircraft safety levels, fuel-use efficiency, and controller productivity have led us to question that plan and to suggest that there may be a middle ground consisting of a highly, but not totally, automated system.

We believe that pursuing the goal of full-automation AERA—with little regard for interim systems or evolutionary development—is a very questionable R&D strategy for ATC. It seems unlikely that a large-scale multi-level AERA system that can effectively handle non-routine events, show stable behavior under dynamically changing conditions, and be virtually immune to reliability problems can be implemented in the foreseeable future. Human controllers may be required to assume control in at least some of these situations, although at present there is no conclusive evidence that they would be able to do so; indeed, some evidence and opinions from the human-factors community suggest that they would not be able to.

The AERA scenario presents serious problems for each of the three major goals of ATC—safety, efficiency, and increased productivity. By depending on an autonomous, complex, fail-safe system to compensate for keeping the human controller out of the routine decisionmaking loop, the AERA scenario jeopardizes the goal of safety. Ironically, the better AERA works, the more complacent its human managers may become, the less often they may question its actions, and the more likely the system is to fail without their knowledge. We have argued that not only is AERA's complex, costly, fail-safe system questionable from a technical perspective, it is also unnecessary in other, more moderate ATC system designs.

Some AERA advocates assert that it is necessary to keep the human out of the time-critical loop to achieve productivity and fuel-use gains. We question that belief as well. AERA may well achieve 100 percent productivity increases in the en route high and transition sectors, and it may indeed facilitate more fuel-efficient air operations. But if the controller work force almost doubles, as expected, by the time AERA comes on-line, and AERA's domain of applicability is limited to the

[1]The Rand Corp., R-2698-FAA, November 1981.

simplest of sector types, its ultimate effect may hardly be felt, since the actual ATC bottlenecks occur elsewhere. Further, greater fuel efficiency comes from many sources—some as simple as present-day relaxation of procedural restrictions, some as complex as the planning modules of AERA and Shared Control. AERA may meet the goals of ATC by 2000, but the costs incurred along the way will be very great—in dollars, in fundamental research that must be completed, and in restrictions on the controller's role.

Ultimately, the AERA scenario troubles us because it allows for few errors or missteps. The right choices have to be made at the right times, or a failed AERA scenario would degrade to a more costly and delayed version of the Baseline scenario. In the attempt to construct a totally automated ATC control system, unacceptably high possibilities and costs of failure overshadow the potential rewards of success.

Our main conclusion is that such an overwhelming dependence on technology is simply unnecessary. If the planned AERA scenario were altered only slightly, it would be essentially equivalent to the Shared Control scenario. All of its technical building blocks are present in Shared Control:

- Air/ground datalink communication.
- Strategic planning (profile generation and alteration) and operator displays.
- Tactical execution.
- Track monitoring and alert.

Missing, however, is the right principle for piecing these building blocks together. Under AERA, they would be fully integrated into a single problem-solving system which extends its capabilities by infrequently requesting human action; under Shared Control, the building blocks would themselves be extensions of human capabilities. Operationally, this shift in perspective requires two modifications of AERA plans:

- The role of man under AERA would be expanded so that he is routinely involved in the minute-to-minute operation of the system.
- The system would be constructed as a series of independently operable, serially deployable aiding modules.

The state of the art in ATC problem-solving techniques does not validate the minimal AERA human role; neither does established knowledge about human limitations or capabilities in this domain. Insisting that man be essentially automated out of such a critical control system is an unnecessarily high-risk approach.

If the system is designed to support him, we would expect the future ATC specialist to take a very active and creative role in manipulating his aiding modules. Safety could be assured by assigning the machine primary responsibility for routine separation assurance tasks at the lowest levels. The specialist should be responsible for comprehending situations at high levels of abstraction and activating modules to meet the ever-changing demands of those situations. He should be able to adjust a module's parameters and its relationships to other modules so that instead of simply monitoring the machine's preprogrammed sequence of instructions, he actually controls the outcome. He should be given the authority to determine which operation the machine performs and which he performs. He should be given the opportunity to learn all of this gradually and to influence the system's design before it is finalized.

This shift in perspective captures the spirit of this report. Specifications of module capabilities and their sequence of implementation are best left to designers who are intimately familiar with the engineering details. We have presented just one of many alternatives in which man has a significant ATC role; the details of the system design need refinement and may indeed undergo great change in the process. For example, our Shared Control scenario suggests implementing digital communications before providing any planning aids at all. Perhaps events will dictate otherwise—a late DABS introduction and an early development of automated planning techniques could reverse this sequence. Fielding a planning aid first as a stand-alone module would not compromise the Shared Control scenario in any way. The essence of the Shared Control scenario is reflected in its name—man and machine must work together and *share* in the overall control function of ATC.

Our key concern is that the human specialist's unique capabilities be acknowledged and the technical uncertainties of an AERA-like system be recognized and dealt with before too much of the Baseline scenario comes to pass. If this is not done, we risk relying solely on an unproven, costly technology to meet the nation's demands for ATC service. We have shown not only that there is a feasible alternative, but also that this alternative may result in lower costs, a higher level of performance, and a more satisfying role for the personnel who will be responsible for moving air traffic safely and smoothly.

Appendix C

OTA CONFERENCE ON THE NATIONAL AIRSPACE SYSTEM PLAN

ATTACHMENT C-1: AGENDA AND LIST OF PARTICIPANTS

Agenda: OTA Conference on the National Airspace System Plan, Apr. 1-2, 1982

Thursday, Apr. 1

9:00-9:10	**Welcoming Remarks and Introductions**
9:10-12:00	**Growth of Aviation**
	Summary of Working Group 1 and 2—H. Clark Stroupe
	FAA Forecast Methods—David Lewis
	Discussion: Factors influencing aviation growth Responsiveness of FAA plan to growth and need for services
12:00-1:30	**Lunch**
	Guest Speaker: J. Lynn Helms Administrator Federal Aviation Administration
1:30-4:30	**Implementation of FAA Plan**
	Summary of GAO Studies—Tony Csicseri
	Discussion: Technological risks Implementation problems Scheduling Flexibility and preservation of options
4:30-5:30	**Reception**

Friday, Apr. 2

9:00-12:00	**Effects on Airspace Users**
	Summary of Questionnaire Responses—Larry Jenney
	Discussion: Potential benefits and problems Difficulties during transition Implications of automation Consolidation of facilities
12:00-1:30	**Lunch**
	Guest Speaker: Philip J. Klass Senior Avionics Editor Aviation Week & Space Technology

1:30-3:30 **Cost and Funding Issues**

Summary of Questionnaire Responses—Larry Jenney

Impact of User Fees—David Lewis

Discussion:
- User fees and other funding strategies
- Operating and maintenance costs
- Allocation of revenues

3:30-4:30 **Summation and Concluding Remarks**

Review of Key Issues

- Recommendations for Additional Study

OTA Conference on the National Airspace System Plan, Apr. 1-2, 1982

John L. McLucas, *Chairman*
President, Comsat World Systems

Ward Baker
Airline Pilots Association

Frederick Bradley, Jr.
Vice President
Citibank, N.A.

Samuel C. Colwell
Director, Market Planning
Fairchild Industries, Inc.

Barbara Corn
BD Systems, Inc.

Anthony Csicseri
U.S. General Accounting Office

Elwood T. Driver
Former Vice Chairman
National Transportation Safety Board

Thomas S. Falatko
Deputy for Transportation and Civil Aviation
U.S. Air Force

Matthew Finucane
Director
Aviation Consumer Action Project

Rod Gilstrap
Director
Flight Safety and Operations
United Air Lines

William T. Hardaker
Assistant Vice President
Air Transport Association

William Horn, Jr.
National Business Aircraft Association

Victor J. Kayne
Senior Vice President
Technical Policy and Plans
Aircraft Owners and Pilots Association

David Lewis
Congressional Budget Office

John Leyden
Executive Director
Public Employees Department
AFL-CIO

Kingsley G. Morse
Chairman
Regional Airlines Association

Gilbert F. Quinby
Consultant

J. Donald Reilly
Executive Vice President
Airport Operators Council International

Harrison Rowe
Bell Laboratories
Crawford Hill Laboratory

Robert C. Seamans, Jr.
Professor of Environment and Public Policy
Massachusetts Institute of Technology

Robert Simpson
Flight Transportation Laboratory
Massachussetts Institute of Technology

H. Clark Stroupe
Vice President
Booz-Allen & Hamilton, Inc.

Richard W. Taylor
Vice President
Boeing Commercial Airplane Co.

David Thomas
Consultant
General Aircraft Manufacturers Association

Vincent Volpicelli
Supervising Engineer
Port Authority of New York and New Jersey

ATTACHMENT C-2: SUMMARY OF QUESTIONNAIRE RESPONSES

Summary of Questionnaire Responses

Participants in the OTA Conference on the National Airspace System Plan were asked to complete a questionnaire outlining their views on FAA's proposed program of improvements in the ATC system. Responses were received from 16 of the 25 participants. Replies from others were promised but not available in time for inclusion in this summary. For this reason, the material presented here should not be interpreted as representing the views of all conference participants.

Responses are summarized under headings that correspond to items in the questionnaire. In some cases, the responses to related questions have been combined because of the overlap in content. All items are presented in a common format—a brief characterization of the replies as a whole followed by a few excerpts to illustrate the variety of views and some of the particular points made by respondents.

It is not the purpose of this summary to suggest a majority view or to attempt to frame what might be construed as a "conference position." Rather, the document was used at the conference to provide participants with a preliminary indication of their colleagues' views, with the object of furthering discussion on the points to be addressed by the conference.

Growth

What are the prospects for growth and where is it likely to occur?

Many respondents indicated that FAA's forecasts of aviation growth are too high. They foresaw little or no growth in air carrier activity. They regarded commuter airlines and business aircraft as the sectors most likely to experience significant growth in the future.

Excerpts:

—"I have been amazed at how constant the number of air carrier aircraft has been over the last decade or so. With the growth of short haul/commuter airlines, I would expect the air carrier (fleet) to continue about as is and the commuter and GA (sectors) to experience a lot of growth."

—"The FAA's forecasts appear to be optimistic in view of the current economic plight of the aviation industry . . . . The number of aircraft operations rather than passenger enplanements should form the foundation for any improvements" (to the system).

—"The FAA's latest forecast of itinerant air carrier aircraft operations at airports with FAA traffic control appears reasonable . . . . They are becoming more reasonable with each annual update, regarding passenger enplanements and air carrier aircraft operations."

—"Demand placed on the system by the general aviation fleet could conceivably double by the year 2000 . . . due to . . . continued growth in the turbo-jet and turbo-prop and rotary-wing segments of the fleet."

—We view with some caution the (FAA) general aviation projections, particularly in view of the continually declining rates of production of small aircraft and the economic and related factors responsible for this decline (fuel costs, interest rates, student starts).

What factors are most likely to influence growth?

Virtually all respondents cited economic factors as the key determinants of aviation growth. They did not see aircraft or avionics technology per se as a major factor. Many felt that the lack of airports or adequate airport facilities could become a major constraint, and several were concerned that regulatory restraints—notably airport restrictions—could slow GA expansion.

Excerpts:

—"In the past, the business cycle and economic climate have influenced the demand for air travel most heavily, and we see no basic change from this correlation."

—"Business aviation growth will continue, but it will never approach the large increases of 1978-1979 . . . . The low growth rate of 1979-1980 is an indicator of how much the economy can affect the purchase of aircraft."

—"Under deregulation, it is not clear whether they (air carriers) will be financially able to continue modernization."

—"We expect no major technology breakthrough during the decade of the 1980's that would again revolutionize air travel."

—"Increased airway capacity and reduced separation standards are necessary, but they will be of no avail if there is no place for the traffic to go . . . . If more new airports are not in the planning stages in 1982, the planned sophistication of the airway system will come to naught."

—"The present restriction on flights at saturated airports will, if not alleviated, be a serious negative factor."

National Airspace System Plan

Does the Plan adequately respond to the needs of aviation?

One respondent had a succinct answer to the question: "Yes (finally)." Indeed, nearly all respondents replied affirmatively to the thrust of this question. Some expressed concern, however, about the absence of supporting detail in the NAS Plan.

Excerpts:

—"The FAA Plan is primarily a management document for the U.S. Government to handle what they forecast will be a massive increase in aircraft growth . . . . Because of my doubts concerning the validity of the forecasts, I feel that the time frames for equipment purchase and facility consolidation are highly suspect."

—"The FAA Plan represents an impressive planning effort . . . . (But it) is incomplete as a vehicle for truly evaluating whether it can satisfy the user's needs. The Plan describes primarily an ATC system framework (hardware, software, functional capabilities), but does not describe either how the system will operate or the potential benefits."

—The Plan "seems to give more a management overview rather than the technical considerations" that led to specific decisions.

—"General aviation, which shows the highest fleet growth, may not be receiving benefits commensurate with their contribution."

—There seems to be a noticeable gap in meaningful programs to increase capacity . . . at airports and in the terminal airspace, particularly in high-density areas. This element of overall aviation system capacity is identified as a major constraint, but major programs are not included.

What elements of the Plan pose the greatest technological risk?

Though they thought that the elements of technology in the NAS Plan are within the state of the art, respondents expressed some concern about the integration of those elements and their impact on the people who operate and use the ATC system. They singled out two areas: 1) the design of a new computer system (hardware and software) and 2) airborne communications links, namely the Mode-S transponder and TCAS (Traffic Alert and Collision Avoidance System).

Excerpts:

—"The development of a host [replacement] computer which uses existing software from the 9020 programs with 'minimal modifications' sounds promising, but . . . the lack of top-down structured design in the present computer software (due to its evolutionary development) all add up to an enormous and complex rehosting software task."

—"The ability to design and transition to a new ATC computer system which effectively utilizes the human controller . . . [and] captures the advantages of higher orders of automation may be the greatest risk."

—"The greatest technological risks involve the reliability of the system and the capability of the human element to perform in the event of a system failure."

—"Mode S is fraught with potential problems because people will not want to get data out of a black box unless they can check it by talking it over with the man on the ground."

—(With Mode S and TCAS,) "interference, multipath propagation, system architecture, (and) data rate will all affect system performance."

What problems might be encountered in implementing the Plan?

Respondents foresaw several difficulties and felt that the Plan does not adequately address questions of user acceptance, operational safety, costs, and the implications of automation. Many also felt that managerial problems would be encountered.

Excerpts:

—"Pilots will not trust new equipment without thorough checkout."

—"The greatest problem . . . will be one of a financial burden on the FAA and the aviation user community."

—Automated En Route Air Traffic Control (AERA) and the Mode S transponder appear to be little more than concepts at this time. A great deal of discussion needs to be carried on between the users and the FAA to determine the basic designs of these systems.

—"The extensive computer-to-computer conversations and black-box-to-black-box coordination . . . necessary in a computer decisionmaking process will require intricate communications linkage and backup."

—"The funding, management and political support of a reduction in jobs and manned facilities of the magnitude proposed will probably be the most difficult to accomplish."

—"With all or the majority of the funds coming from the direct users of the system, unrealistic cost projections, manifesting themsevles in major budget overruns . . . could threaten the entire plan . . . . Only one implementation schedule has been revealed. The FAA fallback position (if actual demand does not match the forecast and

funding is too slow or too low or both) is not discussed."

Is the schedule realistic?

No consensus emerged. Though some thought the schedule was workable, others considered it too slow or too fast. There was also some criticism of FAA's failure to consider airport capacity and other restraining factors.

Excerpts:

—"It is realistic—if money is no object. However, the matter of financing may change the schedule."

—"The schedule is characteristically optimistic . . . . (Yet) this is clearly to be preferred from a safety standpoint over having the system's capacity expansion lag behind the demand."

—"The proposed schedule, while optimistic, already contains delays in availability of needed services."

—"The schedule may perhaps be too slow to keep up with demands, even if the forecasts are on the high side."

—"It isn't clear just how a 100 percent growth between 1980 and 2000 in aircraft operations and passenger enplanements will be handled at the airports that are already saturated . . . . Very little of the NAS Plan addresses (airport) capacity increases comparable to the (traffic) forecast."

—"The schedules as presented in the majority of the programs are pie-in-the-sky; many of the programs have been a part of the FAA for many years and delay has been a constant factor."

—"Based on past experience . . . automation of new concepts of the magnitude descibed in the Plan may take at least twice as long as originally estimated. The Plan may be too ambitious since we do not agree with the FAA projections of fleet size for air carriers and commuters."

What other options should be pursued?

Respondents provided a wide range of suggestions. Some suggested changes in timing or tactics; others advocated putting more emphasis on airborne systems; and a few recommended a fundamental reevaulation of how ATC services are to be provided.

Excerpts:

—"From a strategic standpoint, the FAA plan is a good one . . . . Program-by-program and project-by-project, there will be a need for rethinking options."

—"The FAA choices represent the best chances for success with the fewest risks. Other possible choices, such as the use of satellite technology for navigation and position reporting, are excellent candidates for succeeding systems and should be kept in the forefront for test and evaluation. However, system improvements, as contained in the Plan, should not be delayed for something that might be better in the unknown future."

—"The 9020 computer should be upgraded . . . . A greater exchange of information between facilities and between FAA employees and the pilots is necessary . . . . We must slowly allow the computer . . . to assist the controller in making his decisions."

—"A competitive, single (computer) procurement with demonstration prior to award is one alternative that should be investigated."

—"Major technology options to be pursued should include utilization of airborne data processing capability in the development of such programs as integrated flow management and automated en route ATC (AERA) . . . . Our concern is with the apparent lack of involvement of tie-in of the 'smart airplane' in the FAA's automation plan."

—"Priority should be given to completion of the FSS (Flight Service Station) modernization, which has safety connotations."

—"The FAA communication plan envisions creating what is in effect a nationwide long-lines network . . . . Will this really be cheaper than buying communication services?"

—"Look at feasibility of converting (ATC functions) to private corporation concept and compare overall costs and efficiency."

Effects on Users

What benefits are likely to result from the plan?

Respondents agreed that a major benefit of the new ATC system would be the ability to handle more aircraft safely and efficiently. Major benefits would accrue to air carriers and business aviation. The magnitude and importance of the benefits to private GA were not perceived to be as clear.

Excerpts:

—"Greater efficiency and safety of operations are major benefits to the users. Increased capacity to handle growth must be pursued when the alternative would be to constrain growth."

—"Air carrier operations will benefit . . . in terms of improved safety, flight efficiency and capacity. However, these benefits will be small until the post-1990 time period."

—"Increased automation, distributed processing, remote maintenance monitoring, and air-to-air plus air-to-ground data links will make the navigation and air traffic control system substantially more stable and reliable."

—"Improvement in dissemination of weather information, less labor-intensive ATC system (and) in-

creased capacity of ATC system—if everything works out as planned."

—"Any improvements in the ground computer capability that would allow the business flyer to use this equipment to its maximum usage would be welcomed . . . If the new systm would authorize the (GA) pilot with the proper input and output devices to operate directly into the WX (weather) computer and to file his flight plan directly into the 9020 (computer) or its replacement, it would be most helpful."

—"The increased safety/efficiency resulting from high computer reliability will benefit all users . . . . The major benefit will be the eventual availability of adequate ATC computing capability and Mode-S digital data link."

Identify potential problems and steps that might mitigate them.

Though enthusiastic about technological improvements, some respondents indicated skepticism that higher user fees would be offset by commensurate increases in services and benefits. Because the new system would be more automated, some were concerned that system users might lack confidence in ATC operation.

Excerpts:

—"Transition . . . to a point 10 or 15 years from now where all these benefits of new technology are available will be difficult."

—There would be "less personal interface between users of the system and those managing and controlling it."

—"Emergency operation in case of equipment failure seems not to have been discussed much in the (NAS) Plan."

—"The cost of dual carriage of equipment and the problems of space and weight of this equipment in some aircraft appear to be the only penalties inherent in (the) Plan."

—"Increasingly sophisticated avionics required for operation at certain high-density controlled airports and in certain airspace (TCA's) will restrict the operation of general aviation users who do *not* make the investment."

—"It will be a defensive move for many people—buy this new equipment or be denied access to the airspace. There could be confusion between ILS and MLS—one more switch can be set in the wrong position."

—"Consideration should be given to retaining full ILS service . . . . The full MLS program should be subject to review . . . after suitable operational experience is obtained . . . . Automatic altitude reporting and Mode-S transponders should be mandated as being essential to safe and efficient operation of the ATC system."

—"The result will be more restrictions in operations either through operational procedures/requirements or required equipment."

—(The Plan should provide ways) "to accommodate all segments of aviation in the system by segregating operations based on performance capabilities."

Cost and Funding

How should costs be allocated among the Government and system users?

Respondents' views seemed to be divided among three different approaches. Some favored reestablishment of the Airport and Airways Trust Fund, with some adjustment of tax rates to achieve parity of cost recovery. Others suggested user fees based on aircraft characteristics or avionics equipment. A third view was that fees should be levied in proportion to the use made of, or the burden placed on the ATC system.

Excerpts:

—"The revenue measures which existed under the Airport and Airway Revenue Act of 1970 should be reinstituted."

—"First, the national interest portion must be determined and subtracted. Failure to do this is what discredited past user charges."

—"Whatever (funding) mechanism is adopted should . . . not discourage people from using the system."

—"There is a real danger that funding the (NAS Plan) . . . to a reported 85 percent would have a regressive effect on the very growth in demand that justifies the (new) system."

—"The business community (air carriers/corporate aircraft) would pass the cost on to the passenger or consumer; general/private or nonbusiness aviation would absorb the cost by not flying as much or would cease flying altogether; the cost to the military would come from an increased budget (taxes)."

—"It seems apparent that the general aviation contribution of roughly 5 percent of the cost, as is now the case, is low and should be increased."

—"The airport 'head tax' will never be tolerated by the traveling public."

—"Taxes could also be assessed on the purchase of advanced avionics equipment."

—(Charges should be levied) "depending on the percentage that various groups utilize the system."

How should revenues from user charges be allocated?

Several respondents stressed the importance of employing user fees to cover the cost of capital improvements in the ATC system. Some indicated that surpluses should be avoided, since they would indicate that the fees are too high and therefore would be likely to restrict access to the system. There was wide disagreement about whether operating and maintenance costs of the ATC system should be covered, wholly or partly, by user fees.

Excerpts:

—"The FAA was created in the public interest, and the public should pay for its operation. If the users are to pay for everything, then we should consider abolishing the FAA."

—"Taxes should be levied no higher than necessary to support the program and (should be) tied to a commitment to carry it out."

—"User charges should only be allocated to the Airport and Airway Trust Fund." (The FAA should) "use the Trust Fund for its intended purpose and prevent accrual of a surplus for other purposes."

—"ATC system improvements and R&D should receive the bulk of user charges. A substantial portion should be used for operation and maintenance."

—Trust Fund surpluses "should be applied to the costs of operating and maintaining the system."

—User fee allocations: "System improvements, 50 percent; R&D, 20 percent; airports, 10 percent; operations and maintenance, 20 percent."

—"(User fees) should be allocated to cover all facilities and equipment and research and development costs, roughly 50 percent of the operations and maintenance costs, and full funding of ADAP."

—"A substantial portion should be allocated as aid to airports. None of the user fees should be used for operations and maintenance."

ATTACHMENT C-3: A SUMMARY OF THE CONFEREES' VIEWS

Implementation of the FAA Plan—A Summary of the Conferees' Views at the 1982 OTA Conference

Technological Risks

The FAA Plan contains few technological risks. Most of the elements of the plan reflect the result of extensive use experiences or long-term development.

Modes S and TCAS were endorsed. General Aviation implementation of new transponders should be voluntary to the extent possible, consistent with system safety standards.

Some elements of the plan are "demand independent," and constant efforts to improve system safety are in this category.

A cornerstone of the plan is and should be the immediate initiation of a program to replace the present outmoded ATC automation system with modern *software and hardware* of greater capacity, reliability and flexibility.

Making the transition between the present limited system and a new computer system presents the greatest challenge and risks. If the lives of the current computers are extended unduly, maintenance becomes more difficult and capacity for new functions is limited. If present software is "rehosted" to new computers which are to be used during the next two decades, the choice of computers may limit future systems development. Rehosting to interim "throw away" computers (emulators) has been suggested as a method of providing adequate capacity during the new software development stage without freezing the computer technology or architecture now.

The best way to proceed is a judgment call, and is a matter which this group does not have time to resolve. The FAA judgment is to proceed with a "final" computer replacement selection, and we suggest that good answers will be available only after bids on their proposals are received.

Implementation Problems

The ability of FAA to implement a plan of this magnitude was discussed. Considering the ultimate responsibility of FAA for the safety of those using the system, and the prior success of it and other agencies, such as the National Aeronautics and Space Administration and the military services, in implementing major programs, it was the consensus that FAA should manage the program and obtain necessary additional management and engineering assistance from industry early in the program.

The plan relies heavily on consolidation of manned facilities to achieve economies of scale. Removal of major Government facilities from communities is often difficult, and aviation groups should support consolidations wherever it is shown that costs can be reduced without degrading services.

Scheduling

FAA has not presented sufficient engineering data to assess the proposed schedules. However, the need to rebuild the system and reduce its manpower intensity indicates there should be no delay in starting on the plan.

Flexibility and Preservation of Options

There is good correlation among independent forecasts of trunk air carrier activities, but less confidence in detail of General Aviation forecasts. Implementation of plan should be flexible and adapted to real growth in demand.

The plan appears to provide flexibility to accommodate some changes in direction, such as increased use of cockpit displays and various types of airborne navigation devices, but is not susceptible to such basic changes as whether to replace computers and provide more automated functions if manpower intensity is to be reduced.

Other Concerns

Other concerns are:

1. *Airports:* A companion airport development program is required. Airport capacity in major communities is the ultimate limitation.
2. *Safety:* The plan does not specify the most urgent safety needs in a priority manner, nor is this needed if adequate funding is provided. However, if funding becomes critical, each year's budget must be examined closely to avoid safety items being dropped or deemphasized. Priority determination must fully consider the relationship and interdependency of the separate elements. Failure to do so could adversely affect other systems within the plan if those systems were somehow dependent upon the element in question. A thorough systems look is necessary.
3. *Long-Range Funding:* Unless adequate long-range funding is assured, by both user charges and Government commitment to its share, there is little prospect that the improvements contemplated will be accomplished.
4. *Demand:* Forecast demands may be wrong, and planned capacity may either not meet—or exceed—demands. It may be necessary to adjust schedules to reflect actual demand experience, but the basic concept of providing more automation should be pursued regardless of precise rate of growth.
5. *Man-Machine Interface:* The new sector suite concept pushes reliance on automation much further than current practice. Thus, controllers can handle more traffic per individual, but their duties and responsibilities would be changed significantly. There is little technical risk in the sector suite concept, but care is needed in designing man-machine interfaces to achieve controller efficiency without requiring extraordinary effort or skill.
6. *Wake Vortex:* Increased emphasis should be given to solving wake vortex generation and detection so that acceptance rates can be increased.

Summary

Despite inevitable flaws in the detail elements of the plan, the conference agreed that it merits general endorsement and strong support for long-term funding as a specific element of legislation. One basis for this position was that the proposals within the plan are directed toward the resolution of past and current problems—safety, economics, and reliability— as well as anticipated growth, demand, safety, and reliability problems. There was concern over the proposed use of user-funded trust funds to pay a very high percentage of the operations and maintenance charges of FAA, but this issue must be resolved in the appropriate congressional committees.

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Office of Technology Assessment

The Office of Technology Assessment (OTA) was created in 1972 as an analytical arm of Congress. OTA's basic function is to help legislative policymakers anticipate and plan for the consequences of technological changes and to examine the many ways, expected and unexpected, in which technology affects people's lives. The assessment of technology calls for exploration of the physical, biological, economic, social, and political impacts which can result from applications of scientific knowledge. OTA provides Congress with independent and timely information about the potential effects—both beneficial and harmful—of technological applications.

Requests for studies are made by chairmen of standing committees of the House of Representatives or Senate; by the Technology Assessment Board, the governing body of OTA; or by the Director of OTA in consultation with the Board.

The Technology Assessment Board is composed of six members of the House, six members of the Senate, and the OTA Director, who is a nonvoting member.

OTA currently has studies underway in 11 general areas: energy, international security and commerce, materials, food and renewable resources, health, biological applications, communication and information technologies, oceans and environment, and space, transportation, and innovation.